

KNEE TECHNIQUE GUIDE

Single-Bundle ACL Reconstruction: Medial Portal Technique

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Single-Bundle ACL Reconstruction: Medial Portal Technique

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Anatomic placement of an anterior cruciate ligament (ACL) graft is critical to the success and clinical outcome of ACL reconstruction. Anatomic ACL graft placement is defined as positioning the ACL femoral and tibial bone tunnels at the center of the native ACL femoral and tibial attachment sites. Clinical studies have demonstrated that non-anatomic ACL graft placement is the most common technical error leading to recurrent instability following ACL reconstruction.^{1,2} ACL reconstruction has been commonly performed using a transtibial technique in which the ACL femoral tunnel is drilled through a tibial tunnel positioned in the posterior half of the native ACL tibial attachment site. In the transtibial technique, positioning the ACL tibial tunnel in the posterior half of the ACL tibial attachment site is dictated by the need for the endoscopic drill bit to reach the region of the ACL femoral attachment site and the desire for the ACL graft to avoid impingement against the roof of the intercondylar notch when the knee is in full extension. However, the resulting ACL femoral tunnel is often positioned too high and too deep in the intercondylar notch, away from the native ACL femoral attachment site.

An ACL graft positioned at a posterior tibial and a high-deep femoral attachment site will be vertically oriented in both the coronal and sagittal planes. Biomechanical studies have shown that a vertically oriented ACL graft may resist the motion of anterior tibial translation, but may fail to control the combined motions of anterior tibial translation and internal rotation which occur during the pivot-shift phenomenon.³ The inability of a vertically oriented ACL graft to control these combined motions may result in the patient experiencing continued symptoms of instability and giving-way episodes due to the pivot-shift phenomenon.

In the medial portal technique described in this paper, the ACL femoral tunnel is drilled through an accessory anteromedial (AAM) portal with the knee flexed to 120° or higher (Figures 1A and 1B).



Figure 1A

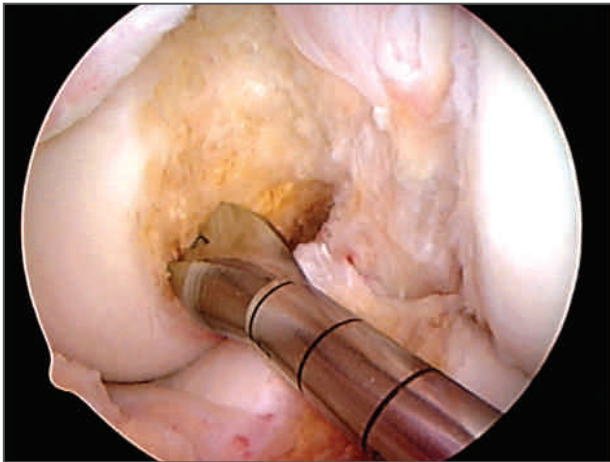


Figure 1B

This approach provides several advantages compared to the traditional transtibial technique:

1. The ACL femoral tunnel is drilled independently of the tibial tunnel, which results in consistent placement of the femoral tunnel within the native ACL femoral attachment site.
2. The angle of the ACL tibial tunnel does not have to be compromised to accommodate drilling of the ACL femoral tunnel. Therefore, the surgeon can opt to drill a steeper and thus longer tibial tunnel. A longer tibial tunnel minimizes the potential for graft-tunnel length mismatch and allows longer bone-tendon-bone graft constructs to be utilized.
3. Although guides are available, the medial portal technique does not require any special guides or instrumentation.
4. Inserting an ACL femoral interference fixation screw through the same medial portal which was used to drill the ACL femoral tunnel minimizes screw-tunnel divergence.
5. The medial portal technique provides improved arthroscopic visualization during drilling of the ACL femoral tunnel since the femoral tunnel can be drilled under ideal arthroscopic conditions, without the loss of joint distention due to fluid extravasation out of the tibial tunnel.

In the medial portal technique, the knee must be flexed to 120° or higher when a rigid guide pin and drill bit are used to drill the ACL femoral tunnel (Figure 2). Hyperflexion is necessary to avoid having the femoral guide pin exit the lateral soft tissues too posteriorly. The peroneal nerve is at risk when the femoral guide pin exits the lateral soft tissues in a too posterior position. Alternatively, the knee may be positioned at 90° of flexion and the ACL femoral tunnel drilled using a flexible guide wire and CLANCY™ flexible reamers.



Figure 2

INDICATIONS AND CONTRAINDICATIONS

The medial portal technique is versatile and can be used with any ACL graft type and for any primary, revision, single- or double-bundle ACL reconstruction. The medial portal technique is particularly useful in the situation where only one of the ACL bundles is torn and the surgeon wishes to preserve the remaining intact ACL fibers and augment the injured posterolateral (PL) or anteromedial (AM) bundle. The only contraindication to the medial portal technique when using rigid guide pins and drill bits is the inability to flex the knee to at least 120°. This limitation may be encountered in some obese patients, in which case consideration should be given to drilling the ACL femoral tunnel using an outside-in technique or using flexible reamers.

PATIENT POSITIONING

It is important to have the ability to achieve full, unrestricted knee flexion during the procedure. The need to flex the knee to greater than 120° of flexion can present problems when a circumferential leg holder is used and the foot of the operating room table is flexed down during the procedure.

The procedure is facilitated by keeping the operating room table flat and using a thigh post and one or two foot supports. This positioning technique allows unrestricted knee flexion to be performed during the procedure and eliminates the need to have an assistant maintain hyperflexion of the knee during drilling of the ACL femoral tunnel.

1. Position the patient supine on the OR table and apply a thigh-length anti-embolism stocking and a foam heel protector to the non-operative leg.
2. Place a padded pneumatic tourniquet high on the operative leg.

Note: The tourniquet is rarely used during the procedure, as adequate joint visualization can be obtained using the Smith & Nephew DYONICS® 25 Fluid Management System.

PORTAL PLACEMENT

Proper portal placement is critical to the success of the procedure. ACL reconstruction using the medial portal technique is facilitated by using three arthroscopic portals (Figure 3):

- The anterolateral (AL) portal, used as a viewing portal to perform diagnostic arthroscopy and meniscal surgery
- The anteromedial (AM) portal, used as both a working and viewing portal
- The accessory anteromedial portal (AAM), used as a working portal to insert instrumentation into the notch and for drilling the ACL femoral tunnel

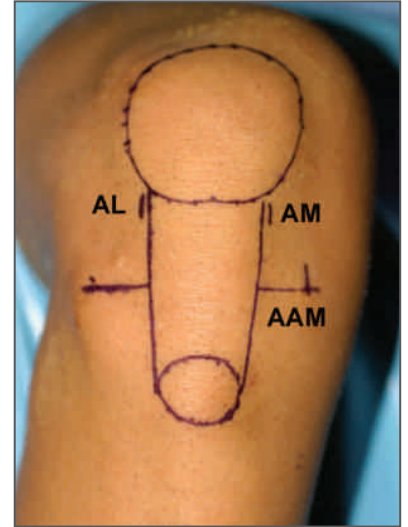


Figure 3

The use of three portals provides the following advantages:

1. The additional medial portal allows the ACL femoral attachment site to be viewed through the AM portal, while working instrumentation is inserted into the notch through the AAM portal. As will be discussed later, viewing through the AM portal is the preferred method to visualize the ACL femoral attachment site.
2. Drilling the ACL femoral tunnel through an AAM portal increases the obliquity of the ACL femoral tunnel relative to lateral wall of the notch, resulting in a longer femoral tunnel length and a more elliptical ACL femoral tunnel aperture compared to drilling the femoral tunnel through the AM portal.

ESTABLISH THE ANTEROLATERAL PORTAL

Establish a high AL portal at the level of the inferior pole of the patella, as close as possible to the lateral border of the patellar tendon using a #11 knife blade. A high AL portal places the arthroscope above the widest part of the fat pad, minimizing interference of the visual field in the intercondylar notch when the knee is placed in hyperflexion. A high AL portal also provides a better, “look down” view of the ACL tibial attachment site.

ESTABLISH THE ANTEROMEDIAL PORTAL

Establishing the AM portal at the correct height above the medial joint line is extremely important to the success of the procedure. The needle position is too low if it enters the knee joint below the level of the roof of the intercondylar notch or passes through the fat pad. Placing the AM portal too low above the medial joint line will result in the arthroscope passing through the fat pad and will place the AM and AAM portals too close together. This will result in the fat pad being dragged into the visual field by the tip of the arthroscope and instrument crowding when the AM and AAM portals are used simultaneously to view the ACL femoral attachment site and drill the ACL femoral tunnel.

1. Place a 30° arthroscope in the AL portal and perform a diagnostic arthroscopy.
2. With the knee flexed between 70–90°, establish the AM portal under direct visualization using an 18-gauge needle.
3. Insert the needle into the knee joint as close as possible to the medial border of the patellar tendon. Direct the needle towards the intercondylar notch, adjusting the height of the needle above the medial joint line as needed to ensure that it comes to lie parallel to the roof of the intercondylar notch.
4. Typically, the needle is located at the height of the inferior pole of the patella or slightly higher. Placing the needle at this level results in adequate spatial separation between the AM and the AAM portal, which is established later, and also results in the AM portal lying above the fat pad.
5. Insert a motorized shaver with a straight or curved 4.5 mm DYONICS® INCISOR® PLUS ELITE® Shaver Blade into the knee joint through the AM portal and resect the ligamentum mucosum. This step will release the fat pad and expose the intercondylar notch.

PLACEMENT OF THE ACCESSORY ANTEROMEDIAL PORTAL

Proper placement of the AAM portal is also critical to the success of the procedure, as it is the most important factor affecting the length of the ACL femoral tunnel. The medial-lateral placement of the AAM portal determines both the length of the ACL femoral tunnel and the shape of the tunnel's aperture. Positioning the AAM portal more medially results in a more perpendicular orientation of the femoral guide pin with respect to the lateral wall of the notch and produces a shorter ACL femoral tunnel and a more circular-shaped tunnel aperture (Figures 4A, 4B, and 4C).⁴ However, placing the AAM portal too medially can result in damage to the medial femoral condyle when the AAM portal is used to drill the ACL femoral tunnel.

Moving the AAM portal more laterally, towards the medial border of the patellar ligament, orients the femoral guide pin more obliquely with respect to the lateral wall of the notch and produces a longer ACL femoral tunnel length and a more elliptically-shaped tunnel aperture (Figures 5A, 5B, and 5C).⁴



Figure 4A

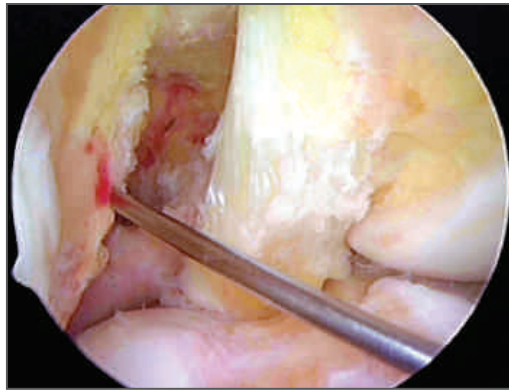


Figure 4B

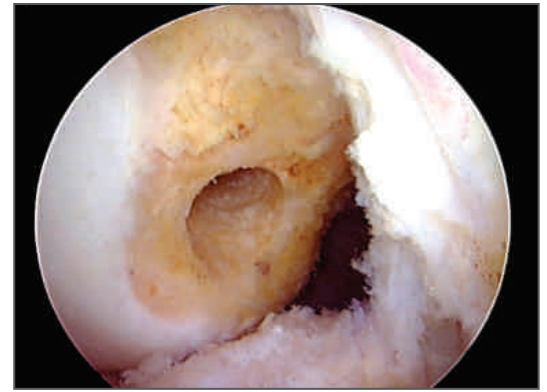


Figure 4C



Figure 5A

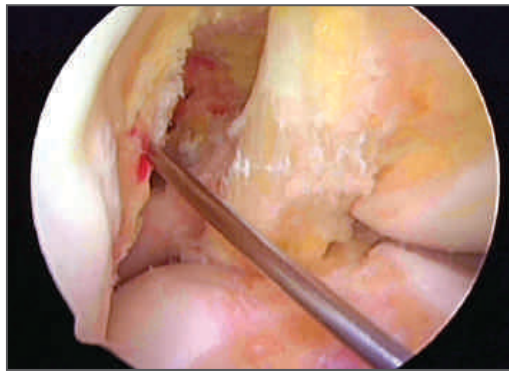


Figure 5B

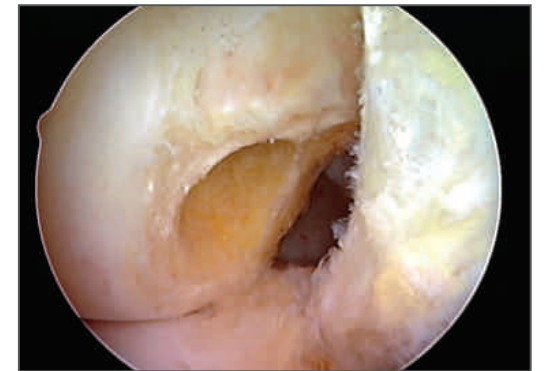


Figure 5C

Based on the ACL graft type and femoral fixation method, adjust the position of the AAM portal to achieve the desired ACL femoral tunnel length. For example, if a bone-patellar tendon-bone ACL graft with interference screw fixation of the femoral bone block is used for the ACL reconstruction, the optimal femoral tunnel length can be in the range of 25–30 mm. For this graft type and fixation method, the AAM portal can be positioned more medially compared to an ACL reconstruction performed using a multiple-stranded hamstring tendon graft with an ENDOBUTTON® fixation device for femoral fixation.

When performing hamstring ACL reconstructions with cortical fixation devices such as the ENDOBUTTON CL ULTRA fixation device, it is optimal to achieve a femoral tunnel length of approximately 40 mm, with the minimum tunnel length being approximately 35 mm. A 40 mm femoral tunnel allows for 25 mm of the hamstring tendon graft to be inserted into the ACL femoral socket when using a 15 mm ENDOBUTTON CL ULTRA fixation device. In the event that a shorter femoral tunnel is drilled, or the surgeon prefers more graft in the femoral tunnel, a 10 mm ENDOBUTTON CL ULTRA fixation device can be used. In this example, a 40 mm femoral tunnel allows for 30 mm of the hamstring tendon to be inserted into the ACL femoral socket.

ESTABLISH THE ACCESSORY ANTEROMEDIAL PORTAL

1. Use an 18-gauge needle to determine the optimal position for the AAM portal. The AAM portal should be located as low as possible above the medial joint line while avoiding the anterior horn of the medial meniscus. Rotate the arthroscope medially to determine if the needle is positioned too closely to the medial femoral condyle. Adjust the position of the portal accordingly.
2. Create the AAM portal using a # 11 knife blade, with the cutting edge of the blade oriented away from the anterior horn of the medial meniscus.
3. Dilate the AAM portal by inserting the tips of the Metzenbaum scissors or a small curved clamp into the incision and spreading the tips in-line with the direction of the portal. This step will ease future instrument passage through the AAM portal.



Figure 6

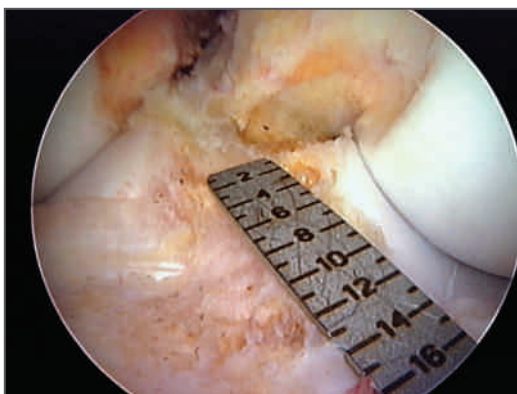


Figure 7

PREPARE THE TIBIAL ATTACHMENT SITE

Carefully inspect the remnants of the torn ACL. An attempt should be made to preserve large tibial stumps and ACL fibers with intact connections from the tibia to the femur.

1. Insert a motorized shaver with a straight or curved 4.5 mm DYONICS® INCISOR® PLUS ELITE® Shaver Blade into the knee joint through the AM portal and resect the mid-section of the ACL. Preserve some of the remaining native ACL fibers at the tibial and femoral attachment sites to aid with anatomic placement of the ACL bone tunnels.
2. Insert a 90° high profile SAPHYRE® Bipolar Ablation Probe through the AM portal and mark the borders of the ACL tibial attachment site (Figure 6). Note that a majority of the ACL tibial attachment site extends anterior to the posterior margin of the anterior horn of the lateral meniscus. The anterior margin of the ACL tibial attachment site lies just posterior to the intermeniscal ligament and the posterior margin lies just anterior to a bony ridge connecting the medial and lateral tubercles (spines). The medial border of the ACL tibial attachment site is defined by a bony ridge, the medial intercondylar ridge of the tibia, which extends anteriorly from the medial tubercle.

DETERMINE THE LENGTH OF THE ACL TIBIAL ATTACHMENT SITE

Insert a TRUKOR® Gauge through the AAM portal and determine the length of the ACL tibial attachment site (Figure 7). Long and wide ACL tibial attachment sites are best restored with larger diameter ACL grafts such as 5- and 6-strand hamstring tendon grafts, a bone-patellar tendon-bone graft, a quadriceps tendon graft, or by performing a double-bundle ACL reconstruction.⁵

ANATOMIC ACL GRAFT PLACEMENT

Biomechanical studies have demonstrated that a single-bundle ACL graft positioned at the center of the ACL femoral and tibial attachment sites best controls anterior tibial translation and the combined motions of anterior tibial translation and internal tibial rotation.³ It also restores knee kinematics more closely to those of the normal knee compared to other anatomic ACL graft placements.³ Based on the reported mean cross-sectional area of the native PL and AM bundles, 60% of the area of an ACL femoral tunnel placed at the center of the ACL femoral attachment site will lie in the region of the AM bundle attachment site, and 40% in the region of the PL bundle attachment site.⁶

ANATOMIC ACL FEMORAL TUNNEL POSITION

Although the clock-face reference method is often used to specify ACL femoral tunnel placement, the clock-face reference method has several shortcomings: it ignores the depth of the notch; there is no agreed upon reference position for the 3 and 9 o'clock locations; it relies on no known anatomic landmarks; and it cannot be used when viewing the ACL femoral attachment site through the AM portal. ACL femoral tunnel placement is more accurately defined and specified using the following methods:

I. Native ACL Footprint

In most cases, remnants of the native ACL fibers are present at the ACL femoral attachment site and these can aid with anatomic ACL femoral tunnel placement (Figure 8).

The view of the intercondylar notch and ACL femoral attachment site changes significantly depending on the arthroscopic portal utilized.

Viewing the ACL femoral attachment site through the AM portal provides an orthogonal view of the lateral wall of the notch, allowing accurate assessment of both the shallow-deep and high-low directions (Figure 9). As a result, the AM portal is the preferred portal for viewing the anatomic ACL femoral attachment site. Viewing the ACL femoral attachment site through the AM portal also eliminates the need to perform a routine notchplasty for visualization purposes. Avoid using a curette, motorized shaver blade or burr to initially perform a notchplasty or to completely remove all of the soft tissue remnants from the lateral wall of the notch as this destroys the remaining native ACL fibers and underlying bony landmarks.

To use the native ACL footprint method:

1. View the lateral wall of the notch with the scope in the AM portal. Insert a 90° high profile SAPHYRE® Bipolar Ablation Probe through the AAM and mark the borders of the native ACL femoral attachment site.
2. Insert a 45° angle microfracture awl through the AAM and mark the center of the ACL femoral attachment site.

II. Lateral Intercondylar and Bifurcate Ridges

When there are no soft tissue remnants present at the native ACL femoral attachment site to use for reference, the underlying bony morphology of the femoral attachment site can provide useful anatomical landmarks to assist with anatomic ACL femoral tunnel placement. Anatomic studies have demonstrated that the ACL femoral attachment site is defined by two osseous ridges (Figure 10).⁶ The lateral intercondylar ridge ("resident's ridge") runs at approximately a 30–35° angle with respect to the long axis of the femoral shaft and represents the upper or superior limit of the ACL femoral attachment

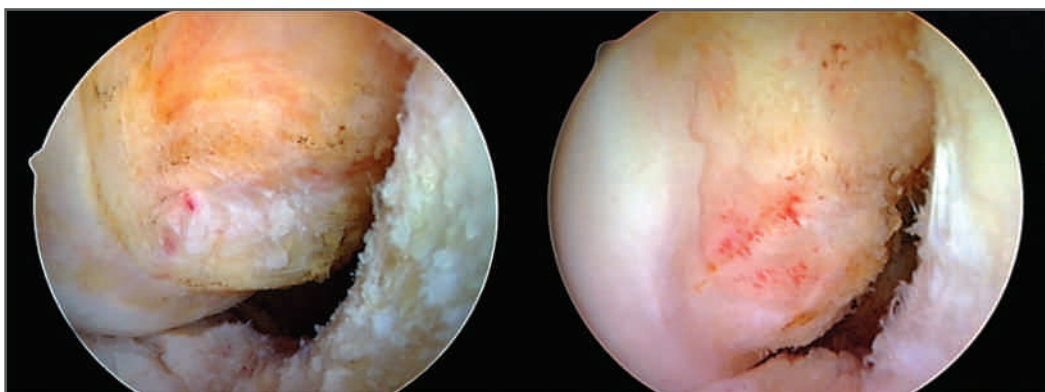


Figure 8

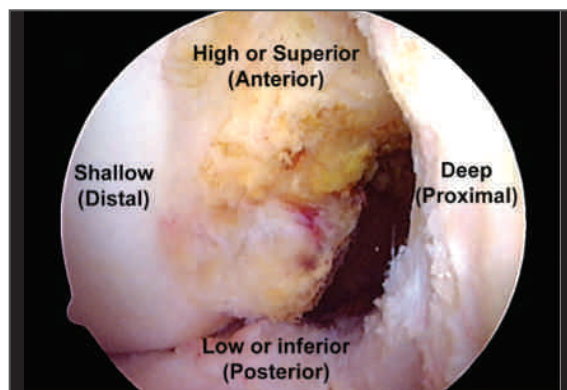


Figure 9

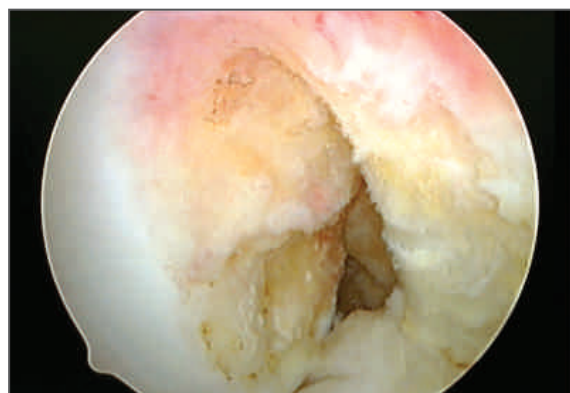


Figure 10

site. The lateral intercondylar ridge has been shown to be present and visible in 88–100% of chronic ACL deficient knees.^{7,8} When present, the lateral intercondylar ridge is critical to anatomic ACL femoral tunnel placement since the ACL femoral attachment site **always** lies below or inferior to this ridge. In some knees it may be possible to identify a second bony ridge, the lateral bifurcate ridge, which separates the attachment sites of the AM and PL bundle fibers.⁶ It is important to remember that because the cross-sectional area of the PL and AM bundles is variable from patient to patient, the location of the bifurcate ridge, when present, does not necessarily represent the true center of the ACL femoral attachment site.

To use the osseous ridges:

1. Use a 90° high profile SAPHYRE° Bipolar Ablation Probe to remove soft tissue along the lower third of the lateral wall of the notch.
2. With the knee at 90° of flexion, identify the lateral intercondylar ridge and the lower border of the articular cartilage margin. The ridge is most easily identified by starting the dissection at the inferior articular cartilage border and working in a superior (high) direction. As the probe contacts the ridge, a distinct endpoint will be encountered. The center of the ACL femoral attachment site in the high-low direction is located half-way between these two landmarks.
3. Use an ACL template or fluoroscopy to determine the shallow-deep position of the ACL femoral tunnel.

III. ACL Template

An ACL template allows the surgeon to individualize the location of the ACL femoral tunnel based on the specific anatomy of the patient. This approach allows for “a la carte” or patient-specific surgery to be performed versus the “one size fits all” approach associated with the use of offset femoral aimers.

1. With the knee at 90° of flexion, place the arthroscope in the AM portal to view the ACL femoral attachment site.

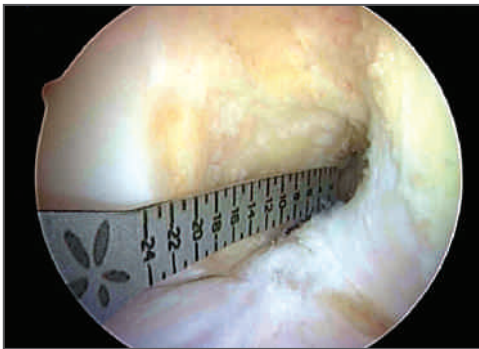


Figure 11

2. Bend the TRUKOR° Gauge to approximately a 45° angle at the 24 mark to allow it to lie flat along the lateral wall of the notch.
3. Insert the TRUKOR Gauge into the knee joint through either the AL or the AAM portal (Figure 11). Inserting the TRUKOR Gauge through the AL portal allows a microfracture awl to be inserted through the AAM portal, giving the surgeon the ability to measure and simultaneously mark the ACL femoral attachment site. However, due to the height of the AL portal above the lateral joint line, in some knees it may be more difficult to position the TRUKOR Gauge further down the sidewall of the notch at the location of the intercondylar ridge. In this situation, it may be advantageous to insert the TRUKOR Gauge through the AAM. The lower position of the AAM portal allows the TRUKOR Gauge to be easily positioned further down the sidewall of the notch.

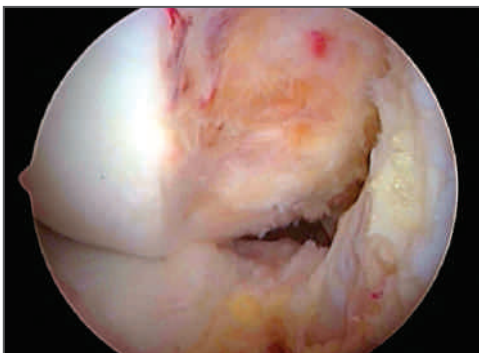


Figure 12A

4. If remnant fibers of the ACL are clearly visible, determine the length of the ACL femoral attachment site along its long-axis using the TRUKOR Gauge (Figure 12A and Figure 12B).

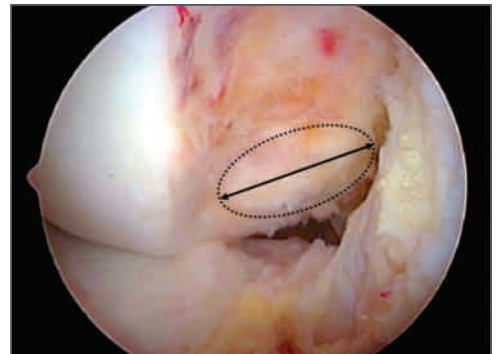


Figure 12B

5. To create an ACL femoral tunnel located in the center of the ACL femoral attachment site, the center of the ACL femoral tunnel should be located at a shallow-deep position that is 50% of the determined length of the ACL femoral attachment site (Figure 13). The high-low placement of the ACL femoral tunnel should be half-way between top and the bottom of the footprint.

6. If no remnant fibers of the ACL are clearly visible:

a. Insert the upper edge of the TRUKOR® Gauge parallel and inferior to the lateral intercondylar ridge and insert the tip of the gauge back to the level of the proximal border of the articular cartilage. The proximal cartilage border represents the deep aspect of the ACL femoral attachment site.

b. The length of the ACL femoral attachment site is determined at the shallow margin where the TRUKOR Gauge touches the articular cartilage border (Figure 14).⁹

c. Insert a 45° microfracture awl through the AAM portal and use it to mark the location of the femoral tunnel. The center of the femoral tunnel should be located at a shallow-deep position that is 50% of the determined distance from the deep aspect of the ACL femoral attachment site to the shallow articular cartilage border. The high-low position of the femoral tunnel should be half-way between the lateral intercondylar ridge and the low (posterior) articular cartilage border (Figure 15).

Note: At 90° of flexion, the native ACL femoral attachment site does not extend completely to the shallow border of the articular cartilage. Therefore, calculating from the shallow border of the articular cartilage slightly overestimates the true length of the ACL femoral attachment site. Calculating the shallow-deep position of the ACL femoral tunnel using 50% of the determined distance from the deep aspect of the ACL femoral attachment site to the shallow articular cartilage border will result in the ACL femoral tunnel being positioned slightly more shallow than the true center of the ACL femoral attachment site.

An ACL femoral tunnel positioned in this location will cover more of the PL bundle attachment site area of the ACL femoral footprint compared to a tunnel positioned at the true center of the ACL femoral attachment site. Therefore, when using the TRUKOR Gauge to determine the ACL femoral attachment site length, it is better to err by marking the femoral attachment site 0.5–1 mm deeper than the calculated 50% position. This will ensure that the ACL femoral tunnel will not be positioned too shallow in the notch.

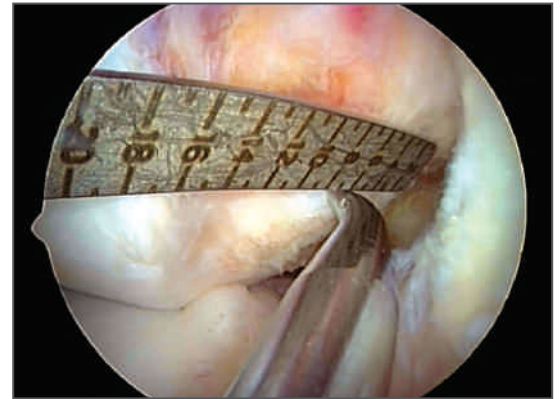


Figure 13

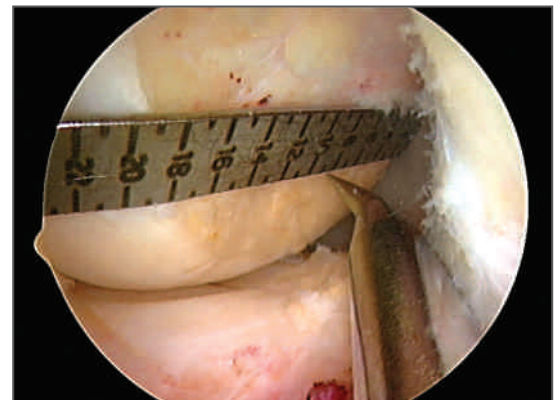


Figure 14

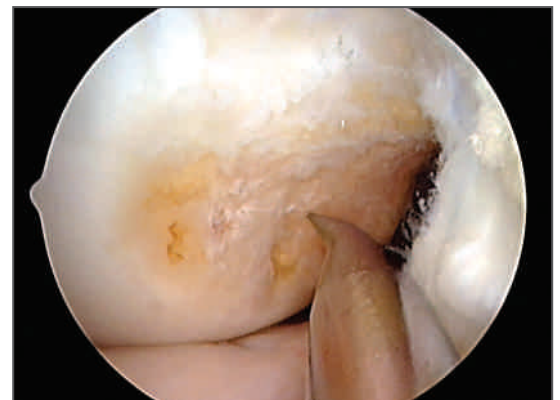


Figure 15

IV. Intraoperative Fluoroscopy

At the present time, intraoperative fluoroscopy is the most accurate method to measure and document ACL femoral tunnel placement.^{10,11} Fluoroscopy gives the surgeon the ability to intraoperatively measure and change the ACL femoral tunnel position, and also serves as a quality control for the ACL femoral

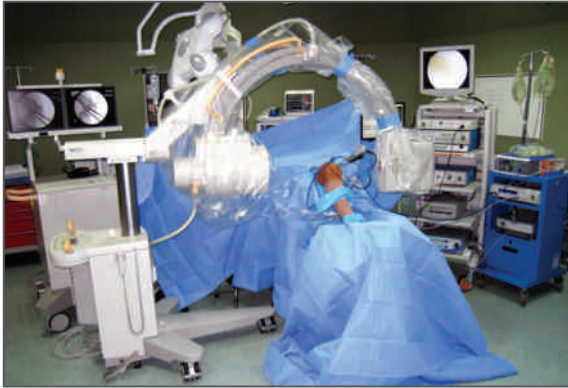


Figure 16A



Figure 16B

tunnel position. With the knee at 90° of flexion and the 45° microfracture awl positioned at the chosen ACL femoral tunnel location, a sterile draped digital c-arm is used to take a true lateral radiograph of the knee (Figure 16A). A true lateral radiograph is one in which the inferior and deep margins of the medial and lateral femoral condyles overlap (Figure 16B).

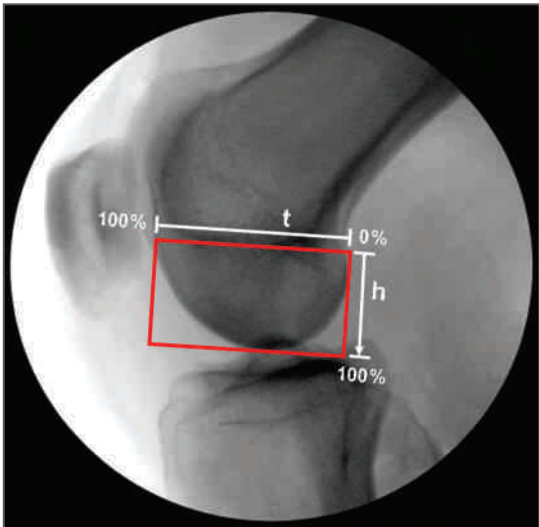


Figure 17A

The grid system described by Bernard and Hertel is used to determine the position of the ACL femoral tunnel (Figure 17A).¹² This method is easy to use, is reproducible, and has been shown to be independent of knee size, shape, and the distance between the x-ray tube and the patient.¹²

1. Draw a tangent to the roof of the intercondylar notch (Blumensaat's line). Draw two lines perpendicular to that line, one at the intersection of the tangent line with the shallow border of the lateral femoral condyle and the other with intersection of the tangent line and the deep border of the lateral femoral condyle. The lateral femoral condyle can be identified by an indentation (Grant's notch) and the fact that the medial femoral condyle extends more distal.
2. Draw another line parallel to Blumensaat's line and tangent to the inferior border of the condyles. Measurements are made as percentages along Blumensaat's line (t), which represents the maximum sagittal diameter of the lateral femoral condyle, and line (h), which represents the maximum intercondylar notch height.

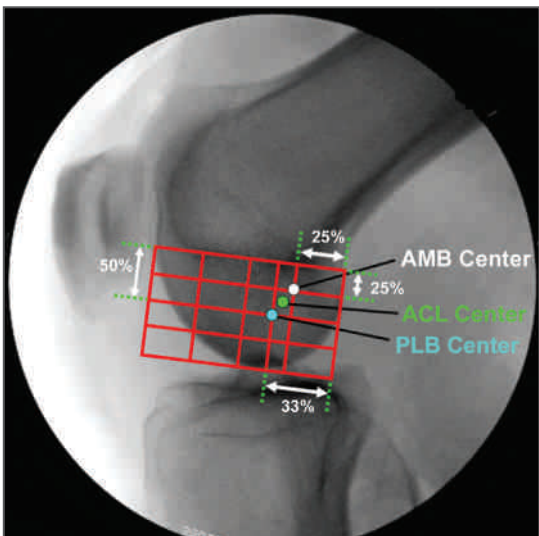


Figure 17B

In Figure 17B, the center of the AM and PL bundles are shown according to the data of Columbet et al.¹³ In this study, the center of the AM bundle was found to lie at a point 25% along Blumensaat's line (t), and 25% along line (h). The center of the PL bundle was located at a point 33% along line (t), and 50% along line (h). Intraoperatively, the Smith & Nephew ACUFEX® Director Application Anatomic Guide software can be used to plot the Bernard and Hertel grid on the c-arm image. Alternatively the images can be saved to an image capture unit and the grid applied later as a quality control check (Figure 18). The microfracture awl position can be adjusted under arthroscopic and fluoroscopic guidance until the desired position is obtained.

Using any or all of the above guidelines eliminates the need to use an offset femoral aimer referencing off the “over-the-top” position to determine the placement of the femoral guide pin along the lateral wall of the notch. Offset aimers can constrain the location of the femoral guide pin and can lead to non-anatomic placement of the ACL femoral tunnel. The above guidelines allow the surgeon to select and verify the location of the ACL femoral tunnel position using established anatomic and radiographic landmarks.

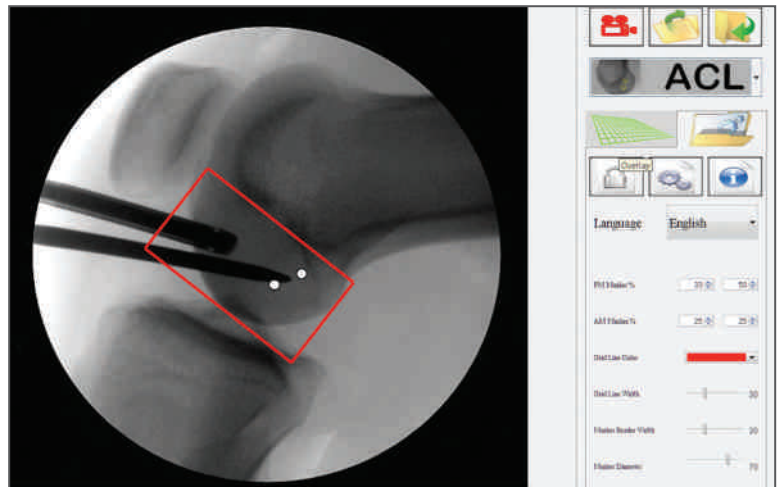


Figure 18

DRILL THE FEMORAL TUNNEL

1. After selecting and confirming the desired location for the ACL femoral tunnel, use a 45° microfracture awl to mark the location along the lateral wall of the notch.
2. Insert a zero-offset ACUFEX® DIRECTOR Endofemoral Aimer through the AAM portal and place it at the desired location for the ACL femoral tunnel. Slowly flex the knee to 120° or higher. Increasing the degree of knee flexion increases the ACL femoral bone tunnel length.

Note: Hyperflexion of the knee results in a loss of joint distension due to external compression of the knee joint capsule by the soft tissues of the thigh. This can result in bleeding and a loss of joint visualization due to encroachment of the fat pad into the notch. To maintain adequate joint distension and visualization, it is necessary to increase the fluid pressure of the Smith & Nephew DYONICS® 25 Fluid Management System up to 120 mmHg while working in the notch with the knee in hyperflexion. Decrease the pump pressure to the normal setting after the ACL femoral tunnel has been drilled and the knee is extended back to 70–90° of flexion. If the fat pad still obscures visualization, limited resection of the fat pad should be performed by inserting a straight or curved 4.5 mm DYONICS® INCISOR® PLUS ELITE® Shaver Blade through the AAM or AM portals.

3. Insert a 2.7 mm drill-tip graduated guide pin through the 0 mm offset aimer and use a small mallet to tap the drill-tip part of the guide pin into the pilot hole created by the microfracture awl (Figure 19A).
4. Keeping the tip of the 2.7 mm drill-tip guide pin in the pilot hole, slowly angle the handle of the endofemoral aimer laterally and tap the guide pin into the lateral wall of the notch until the drill-tip part of the guide pin is fully buried into the bone. This maneuver increases the obliquity of the guide pin relative to the lateral wall of the notch, resulting in a longer femoral tunnel and a more elliptically-shaped tunnel aperture (Figure 19B).⁴ An elliptically-shaped tunnel covers more of the ACL femoral attachment site and more closely reproduces the anatomy of the native ACL attachment site versus a circular-shaped femoral tunnel.⁴



Figure 19A

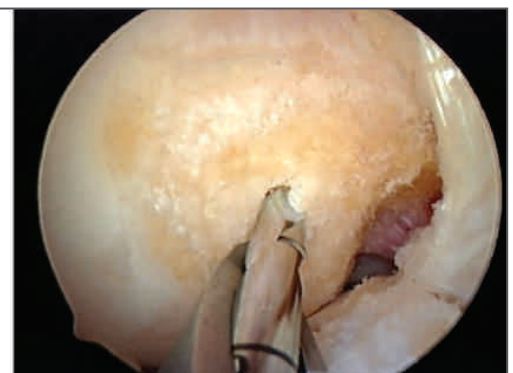


Figure 19B

5. Slowly drill the 2.7 mm drill-tip graduated guide pin through the lateral femoral condyle until the resistance of the lateral femoral cortex is encountered.
6. Note the depth mark on the graduated drill-tip passing pin at the point of maximum resistance. This distance will provide a good estimate of the ACL femoral tunnel length. If the resulting ACL femoral tunnel length is significantly less than desired, it is possible to increase the femoral tunnel length by reversing the guide pin back to the entry point, angling the offset aimer more laterally, and increasing the knee flexion angle. These maneuvers can often redirect the drill-tip guide pin more proximally up the femoral shaft, producing a longer femoral tunnel length.

Note: Do not use power to initially insert the femoral guide pin into the bone. The guide pin will skive off of the pilot hole if power is initially used. Guide pin breakage can also occur if an attempt is made to simultaneously angle and drill the guide pin into the bone under power. To prevent guide pin breakage, ensure that the drill-tip portion of the guide pin is fully inserted into the bone before using power to drill the pin through the bone.

7. Drill the ACL femoral socket using an endoscopic drill bit that corresponds to the diameter of the ACL graft (Figure 20A and 20B).

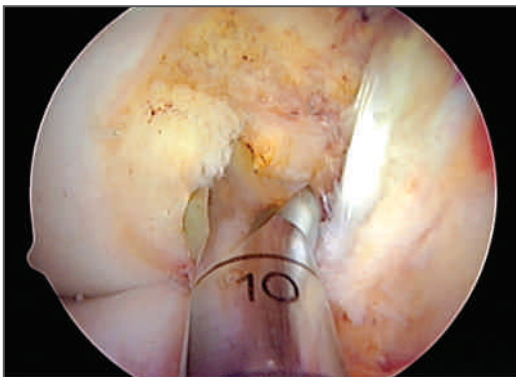


Figure 20A

Note: If using interference screws to fix the ACL graft, the femoral socket can be drilled directly using an endoscopic drill bit that corresponds to the diameter of the ACL graft.

Note: If using an ENDOBUTTON® CL Fixation Device for the femoral fixation, use a 4.5 mm ENDOBUTTON Drill Bit to drill a tunnel through the lateral femoral cortex. Determine the length of the femoral tunnel by noting the mark on the ENDOBUTTON Drill Bit at the time of cortical breakthrough. The femoral tunnel length can also be determined by slowly withdrawing the ENDOBUTTON Drill Bit until the fluted part of the drill bit is felt to engage the lateral femoral cortex. The distance at the femoral tunnel entrance is noted and 10 mm (the length of the fluted part of the 4.5 mm ENDOBUTTON Drill Bit) subtracted to give the femoral tunnel length.

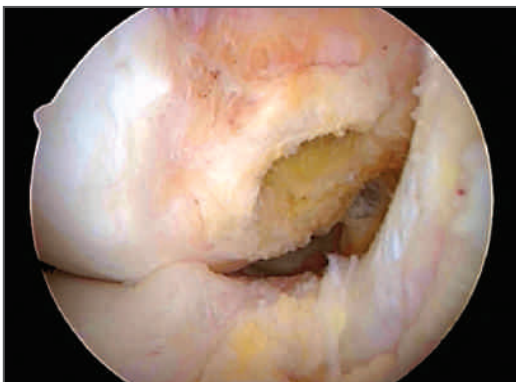


Figure 20B

Knowing the length of the femoral tunnel allows the femoral socket to be drilled all the way to the femoral cortex. Drilling the femoral socket close to the lateral femoral cortex will allow room for the ENDOBUTTON Fixation Device to flip in all situations, eliminating the need to calculate how deep to drill the femoral socket.

Damage to the medial femoral condyle, which can be caused by an endoscopic reamer introduced through the AAM portal, can be avoided by using the “passing pin maneuver” described by Siebold et al.¹⁴ Due to their smaller diameter, this technique is rarely necessary in the case of hamstring tendon ACL grafts. Iatrogenic damage to the cartilage of the medial femoral condyle is more likely to occur in the situation where a

10 mm drill bit is used to drill the femoral socket for a bone-patellar tendon-bone or bone-quadriceps tendon graft. In this maneuver, the femoral guide pin is drilled out through the lateral soft tissues in the usual fashion. To avoid damage to the articular cartilage from the endoscopic reamer, the drilled-tipped end of the femoral guide pin is reversed until the tip of the guide pin is visible in the intercondylar notch.

The guide pin is then angled away from the medial femoral condyle and the cannulated endoscopic reamer inserted over the guide pin into the notch. Once the endoscopic reamer has safely bypassed the medial femoral condyle, the tip of the guide pin is re-inserted back into its original hole in the lateral wall of the notch. Having safely bypassed the medial femoral condyle, the femoral socket

can be drilled in the conventional fashion. To withdraw the endoscopic reamer, the passing pin is withdrawn from the femoral tunnel, the reamer maneuvered into the notch away from the medial femoral condyle and the reamer safely removed from the joint.

If a 3-portal technique has been used, fluid flow and visualization in the notch with the knee in hyperflexion can be facilitated by introducing a motorized shaver blade through the AL portal. The suction on the shaver can be used to maintain fluid flow and to suction bone debris created during the drilling of the ACL femoral tunnel, thus maintaining a clear visual field. The shaver can also be used to resect any portions of the fat pad restricting passage of the endoscopic reamer or obstructing visualization in the notch.

8. Load a #2 or #5 polyester suture into the slotted end of the 2.7 mm drilled-tipped passing pin and pass the free ends of the suture out through the lateral soft tissues, leaving the looped end of the suture in the ACL femoral tunnel.
9. When a multiple-stranded hamstring tendon graft is used as an ACL graft, use the ENDOBUTTON® Depth Gauge to determine the length of the ACL femoral tunnel.
10. Chamfer the edges of the femoral tunnel with an ACL chamfer rasp to minimize abrasion of the ACL graft.
11. In chronic cases with notch osteophytes or in patients with small width notches, a limited wallplasty at the shallow border of the notch is performed using an ACUFEX® Curved Compound Gouge (Figure 21). If required, the wallplasty should be performed after the ACL femoral tunnel has been drilled to avoid lateralizing the position of the ACL femoral tunnel. Use a motorized shaver blade to contour and flatten the wall of the notch.

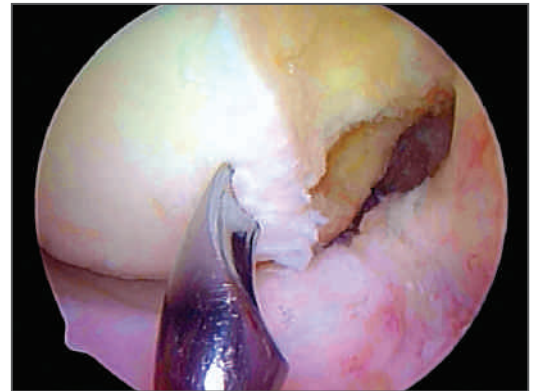


Figure 21

DRILL THE TIBIAL TUNNEL

Place the knee at 70–90° of flexion. While viewing through the AM or AL portal, insert an ACUFEX® Director ACL Tip Aimer set at a 55° angle through the AM or AAM portal into the knee joint. Position the tip of the aimer, 2–3 mm anterior to the posterior margin of the anterior horn of the lateral meniscus and slightly medial to mid-line of the ACL tibial attachment site (Figure 22).

1. Mark the aimer bullet with a surgical marker at the desired tibial tunnel length.
2. Position the bullet medial to the crest of the tibia, in the middle of the skin incision used to harvest the ACL graft. Raise or lower the handle of the aimer until the mark on the bullet is located at the end of the aimer handle when the bullet is flush with the anterior cortex of the tibia. These steps allow a tibial tunnel of a known length to be drilled, thus allowing the issue of graft-tunnel length mismatch to be addressed.
3. Drill a 2.4 mm drill-tip guide pin into the tibia until the resistance of the aimer tip is encountered.

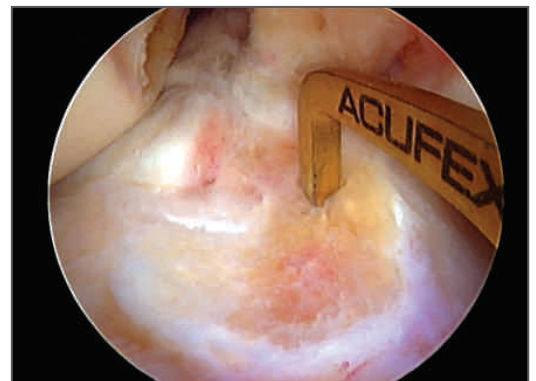


Figure 22

Note: Avoid drilling the tibial guide pin completely into the knee joint as this will result in the guide pin hitting the tip of the tibia aimer and deflecting away from its intended target. Instead, remove the tibia aimer from the joint and use a small mallet to tap the 2.4 mm drill-tip guide pin until it is visible in the joint.

In general, the tip of the tibial passing pin should lay 1–2 mm anterior to the posterior margin of the anterior horn of the lateral meniscus and slightly medial to the mid-line of the ACL tibial attachment site (Figure 23). The most common error made when converting from the transtibial tunnel technique to the anteromedial portal technique is to position the tibial guide pin in the posterior half of the ACL tibial attachment site.

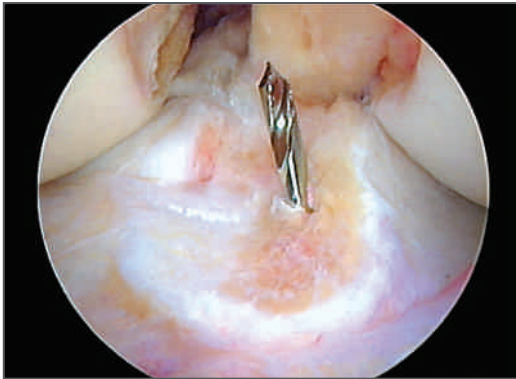


Figure 23

Note: Placement of the tibial guide pin posterior to the posterior margin of the anterior horn of the lateral meniscus will result in the ACL tibial tunnel being placed in the area of the tibial attachment site of the PL bundle. This tunnel placement will produce a vertical ACL graft in the sagittal plane. Positioning the tibial guide pin too far laterally in the ACL tibial attachment site can result in impingement of the ACL graft against the lateral wall of the notch.

Note: Due to the large degree of variability of the intercondylar notch roof angle and the amount of knee hyperextension from patient to patient, it is extremely helpful to use fluoroscopy to confirm correct anterior-posterior placement of the ACL tibial guide pin.

4. Place the knee in maximum extension and obtain a true lateral radiographic view of the knee (Figures 24A and 24B).



Figure 24A



Figure 24B

Note: For soft tissue grafts, which will be centered along the line of the guide pin, the tibial guide pin should lie approximately 4–5 mm posterior to Blumensaat's line (Figure 23). For bone-patellar tendon-bone grafts the tibial guide pin placement can be approximately 2–3 mm posterior to Blumensaat's line since the patellar tendon graft fibers are offset from the bone block and will come to lie posterior to the line of the guide pin.

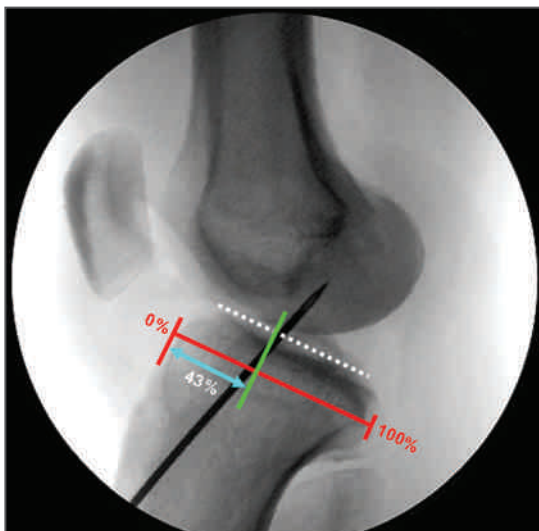


Figure 25

DETERMINE AND ANALYZE THE TIBIAL GUIDE PIN POSITION

The Smith & Nephew ACUFEX[®] Director Application Anatomic Guide software can be used to accurately determine and analyze the position of the ACL tibial guide pin in the sagittal plane.

1. Determine the tibial guide pin position using the method of Amis and Jakob (Figure 24B).¹⁵ The goal is to place the tibial guide pin in the center of the ACL tibial insertion site, which has been shown to lie at 41–44% along the Amis-Jacob line.¹⁶

In Figure 25, the medial joint line is marked by the dotted white line. The Amis-Jakob line (red line) passes through the posterior corner of the widest part of the medial tibial plateau (square posterior border) parallel to the medial joint line. The anterior tibial cortex represents 0% and the posterior tibial cortex 100% of the sagittal width of the tibia. The tibial guide pin position is calculated by dropping an orthogonal line (green line) from the point where the tibial guide pin crosses the

medial joint line onto the Amis-Jakob line. The distance from the anterior tibial cortex (0%) to the orthogonal projection onto the Amis-Jakob line (blue line with arrowheads) is represented as a percentage of the total length of the Amis-Jakob line. The tibial guide pin in this case is located at 44% along the Amis-Jakob line, which places the guide pin in the center of the ACL tibial attachment site.

2. With proper placement of the tibial guide pin confirmed, use a fully fluted cannulated drill bit sized equal to the measured diameter of the ACL graft to drill the tibial tunnel (Figure 26).
3. Small adjustments in the final position of the ACL tibial tunnel can be made by first using a 5 mm drill bit to drill the initial tibial tunnel. Adjustments to the final tibial tunnel position can be made by maintaining and repositioning the tibial guide pin eccentrically in the tibial tunnel using a small clamp. The tibial guide pin can be moved in the desired direction and the tibial tunnel drilled sequentially by 1 mm increments up to the desired size of the tunnel using an endoscopic drill bit.
4. In the situation where the tibial guide pin is malpositioned more than 3–4 mm, the tibial guide pin can be exchanged by leaving the original malpositioned guide pin in place, repositioning the tip of the ACL tibial aimer at the desired intra-articular location, and changing the external starting point of the aimer on the tibia. Leaving the original guide pin in place prevents the new guide pin from tracking up the path of the original guide pin.

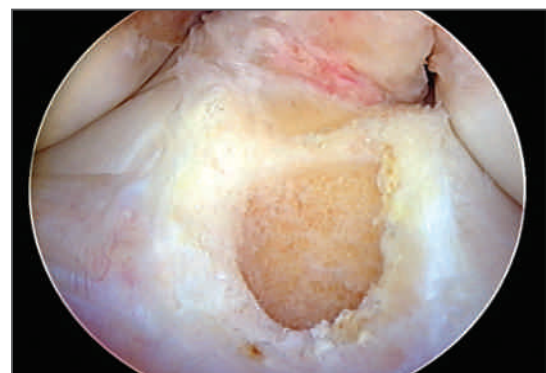


Figure 26

GRAFT PASSAGE

1. Use an arthroscopic probe or grasper to retrieve the suture loop that was left in the ACL femoral tunnel and pull the suture out of the knee joint through the tibial tunnel. Pass the passing sutures for the ACL graft through the suture loop and pass them out of the lateral thigh. The ACL graft is passed into the knee joint using the graft passing sutures.
2. When a femoral bone-patellar tendon-bone or bone-quadriceps tendon ACL graft is used for the ACL reconstruction, the length of the femoral bone block should not exceed 20–22 mm in length, as longer bone blocks may present difficulties during graft passage. Unlike the transtibial technique where the ACL femoral and tibial bone tunnels are collinear, drilling the ACL femoral tunnel through a medial portal results in divergence of the two tunnels. As a result, the femoral bone block of the ACL graft must rotate in the notch away from the PCL to enter the ACL femoral tunnel (Figure 27). If the femoral bone block is longer than 20–22 mm, it may be difficult to get it to rotate in the notch and enter the femoral tunnel. It is often helpful to use an arthroscopic probe as a pulley to redirect the angle of the femoral bone block sutures in the direction of the ACL femoral tunnel.

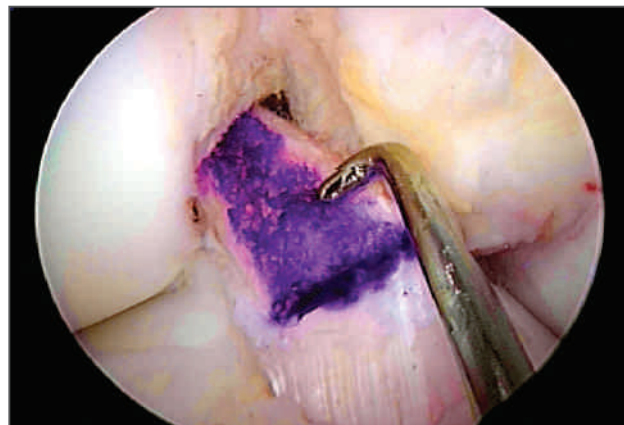


Figure 27

ACL GRAFT TENSIONING AND TIBIAL FIXATION

1. Use the following table to find the correct angle of flexion for tensioning the ACL graft, based on the location of ACL femoral tunnel.

For femoral tunnels placed:	Tension the ACL graft at:
Near the center of the AM attachment site	45°
Near the center of the ACL attachment site	20–30°
Near the center of the PL bundle	0°

2. For multiple-stranded hamstring tendon ACL grafts, use a graft tensioning device applied to opposite ends of the ACL graft limbs and apply 10–15 N of force per strand (40–80 N total).
3. For multiple-stranded hamstring tendon ACL grafts, cycle the knee from 0 to 90° for a minimum of 30 cycles with an 80 N preload applied to the ACL graft using a graft tensioning device.
4. Fix the multiple-stranded hamstring tendon ACL graft at the flexion angle shown in the above table with the graft tensioned to 10–15 N per strand (40–80 N).
5. Insert the 30° arthroscope into the AL or AM portal and check for wall and roof impingement of the ACL graft (Figures 28A and 28B).



Figure 28A

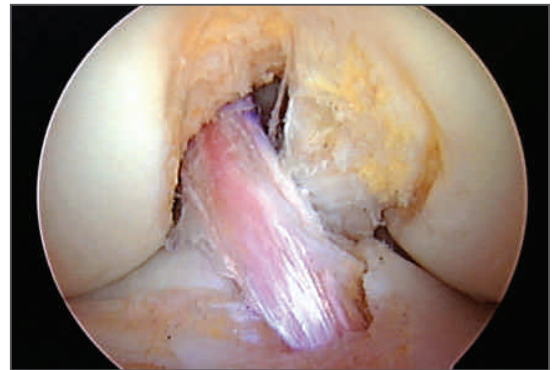


Figure 28B

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