

Avoiding Posterior Cruciate Ligament and Roof Impingement With Transtibial Anterior Cruciate Ligament Reconstruction: Keys to Correct Tunnel Placement

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Summary: Avoiding posterior cruciate ligament (PCL) impingement, avoiding roof impingement, and replicating the tension pattern of the intact anterior cruciate ligament (ACL) are the keys to successful ACL reconstruction. To avoid PCL impingement, the tibial tunnel should be placed in the coronal plane at an angle between 60° and 65° with the medial joint line, and the lateral edge of the tibial tunnel should pass through the apex of the lateral tibial spine. Placement of the tibial tunnel with these 2 criteria usually requires removal of the medial wall of lateral femoral condyle (ie, wallplasty) until the space between the PCL and lateral femoral condyle exceeds the diameter of the graft by 1 mm. The guidewire should be drilled through the lateral hole in the bullet of the guide and enter the notch midway between the PCL and lateral femoral condyle. To avoid roof impingement without a roofplasty, the tibial tunnel should be customized in the sagittal plane 5 to 6 mm posterior and parallel to the intercondylar roof with the knee in maximum hyperextension, which accounts for variability in roof angle and knee extension. We prefer to use the Howell 65 Degree Tibial Guide to place the tibial tunnel with these criteria in the coronal and the sagittal planes. When the femoral tunnel is drilled through and in line with the correctly placed tibial tunnel, and when the back wall of the femoral tunnel is 1 mm thick, the tension pattern in the graft replicates that of the intact ACL. **Key Words:** Anterior cruciate ligament reconstruction—Tunnel placement—Roof impingement—Posterior cruciate ligament impingement—Transtibial technique.

Correct tunnel placement is the key to successful anterior cruciate ligament (ACL) reconstruction.^{13,19–21} Incorrect tunnel placement is the most common cause of loss of motion and failure of an ACL reconstruction.^{13,19,20} Incorrect tunnel placement cannot be overcome by the strongest graft, most effective fixation methods, or carefully controlled rehabilitation program.

Three criteria for correct tunnel placement have emerged from analyzing scientific studies devoted to

tunnel placement, graft tension, and clinical outcomes. These criteria include:

1. Avoiding posterior cruciate ligament (PCL) impingement^{11,21};
2. Avoiding roof impingement^{7–9,13,24}; and
3. Replicating the tension pattern of the intact ACL.^{15,21,23}

Adherence to these 3 criteria improves range of motion and stability, minimizes stress in the ACL graft and fixation, and improves clinical outcomes.

Definition, Symptoms, and Avoidance of Posterior Cruciate Ligament Impingement

Impingement of the ACL graft against the lateral edge of the PCL during knee flexion is termed PCL impingement. PCL impingement disturbs the function of the knee because the tension in the graft in flexion is higher than

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in the intact ACL.²¹ The high tension in the graft in flexion causes symptoms of either a loss of flexion or an increase in anterior laxity.¹¹

Avoiding PCL impingement requires an understanding that the placement of the tibial and femoral tunnels in the coronal plane determines whether the ACL graft impinges against the PCL during flexion. For the surgeon who prefers to drill the femoral tunnel through the tibial tunnel, the tibial tunnel is the key tunnel because the tibial tunnel determines the placement of the femoral tunnel. In other words, if the tibial tunnel is correctly placed, then the femoral tunnel is correctly placed.²¹

PCL impingement is avoided by placing the angle of the tibial tunnel in the coronal plane between 60° and 65° with the medial joint line, and by placing the lateral edge of the tibial tunnel through the apex of the lateral tibial spine (Fig. 1). Studies have shown that placement of the angle greater than 70° increases graft tension in flexion, limits flexion, and increases anterior laxity,^{11,21} and placement of the tibial tunnel medial to the medial tibial spine limits flexion.^{19,20}

We prefer to use the Howell 65 Degree Tibial Guide (Arthrotek, Inc., Warsaw, IN, <http://www.arthrotek.com>) to place the tibial tunnel without PCL impingement. The tip of the guide, which is 9.5 mm wide, is used to gauge the space between the PCL and lateral femoral condyle. Often the notch is too narrow and a wallplasty is performed until the space between the PCL and lateral femoral condyle exceeds the diameter of the graft by a millimeter (Fig. 2). The alignment rod, which is inserted into the handle of the tibial guide, is oriented parallel to the joint line and perpendicular to the tibia to place the angle of the tibial tunnel at 65° (Fig. 3). The guidewire is drilled through the lateral hole in the bullet, which places the lateral edge of the tibial tunnel so that it passes through the apex of lateral tibial spine.

Definition, Symptoms, and Avoidance of Roof Impingement

Impingement of the ACL against the intercondylar roof during knee extension is termed roof impingement. Roof impingement disturbs the function of the knee because the contact pressure increases between the graft and the roof, which occurs prematurely before the knee reaches maximum hyperextension.⁴ The premature increase in contact pressure causes symptoms of either a loss of extension or an increase in anterior laxity.^{8,9,13}

Avoiding roof impingement requires an understanding that the placement of the tibial tunnel in the sagittal plane determines whether the ACL graft impinges against the roof during extension. Roof impingement is avoided by placing the tibial tunnel in the 5 to 6 mm posterior and

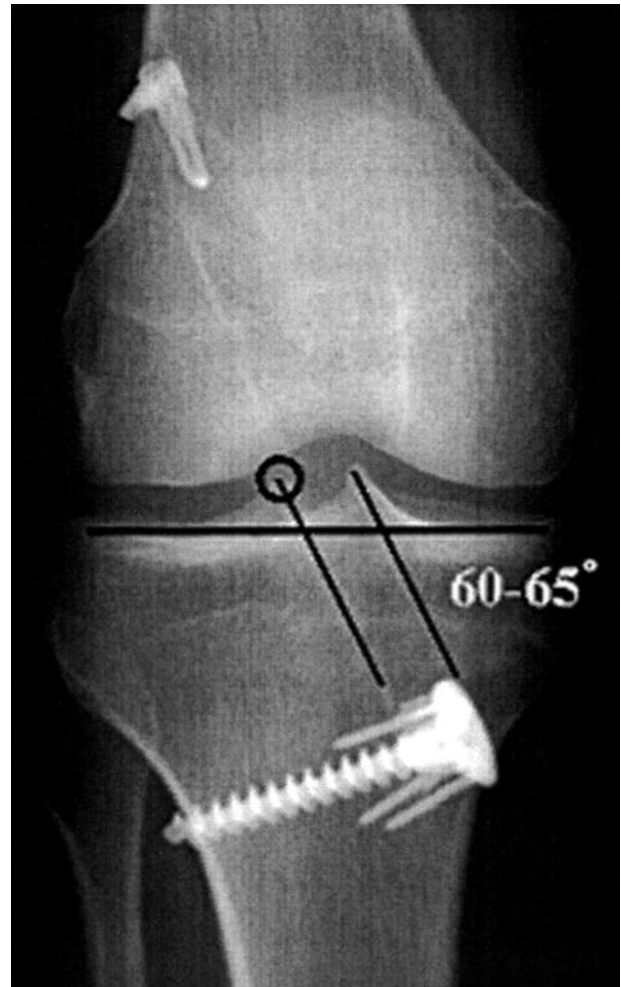
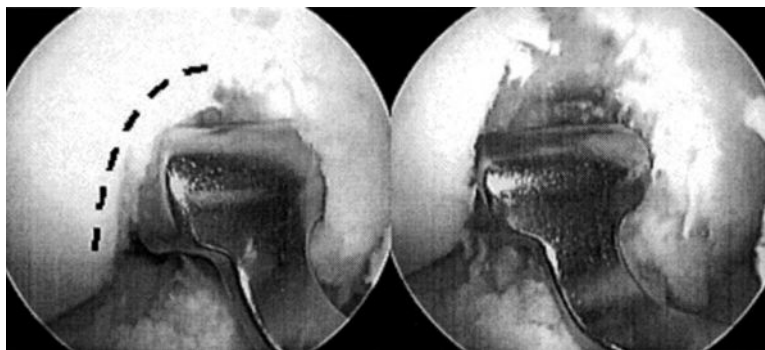


FIG. 1. The tibial tunnel should be placed in the coronal plane at an angle between 60° and 65° with the medial joint line, and the lateral edge of the tibial tunnel should pass through the apex of the lateral tibial spine (circle). Placement of the tibial tunnel at an angle greater than 65° and medial to the apex of the lateral tibial spine causes posterior cruciate ligament impingement.

parallel to the intercondylar roof with the knee in maximum hyperextension. This places the graft anatomically within the pathway of the original ACL.⁹ Studies have shown that placement of the tibial tunnel anterior to the intercondylar roof increases contact pressure in extension, limits extension, and increases anterior laxity.^{6,7,9,19,22} It is best to avoid roof impingement by customizing the placement of the tibial tunnel and not by performing a roofplasty, because a roofplasty causes high graft tension, increases anterior laxity, overstresses the graft and fixation, and may interfere with graft remodeling.¹⁶

The placement and the angle of the tibial tunnel in the sagittal plane should be customized for the unique anat-

FIG. 2. The tip of the tibial guide, which is 9.5 mm wide, is inserted between the lateral femoral condyle and posterior cruciate ligament (PCL) to gauge the space for the graft. A wallplasty is performed with use of an angled osteotome until the space between the lateral condyle and PCL exceeds the diameter of the graft by a millimeter (dotted line). Almost every knee requires some level of a wallplasty because the width and round shape of the anterior cruciate ligament (ACL) graft is larger than the narrower, spindle-shaped intact ACL.



omy of each patients' knee.⁷ Customized placement of the tibial tunnel is required for each knee because roof angle varies widely from 23° to 60° and knee extension varies widely from 5° to 30°.^{7,22}

We prefer to use the Howell 65 Degree Tibial Guide to place the tibial tunnel without roof impingement. The tip of the guide is positioned inside the notch with the bump on the guide facing the intercondylar roof. The knee is placed in maximum hyperextension, and the handle of

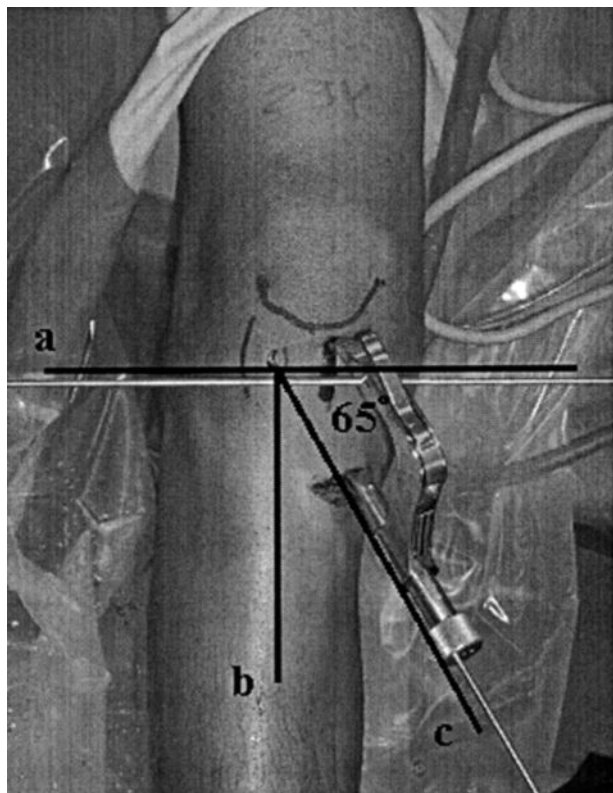


FIG. 3. An alignment rod, which is inserted into the handle of the tibial guide, is used to align the angle of the tibial tunnel in the coronal plane between 60° and 65°. When the alignment rod is oriented parallel to the joint line (A) and perpendicular to the tibia (B), the angle of the tibial tunnel is 65° (C).

the guide is lifted to lock the guide in place. The guidewire is drilled through the lateral hole in the bullet so that it passes through 5 to 6 mm posterior and parallel to the intercondylar roof in the sagittal plane (Fig. 4).

Replication of the Tension Pattern of the Intact Anterior Cruciate Ligament

Tension in the graft higher than in the intact ACL has penalties,¹⁵ which include excessive graft wear at the femoral tunnel,⁵ poor vascularity, myxoid degeneration, inferior mechanical properties of the graft,^{14,25} posterior subluxation of the tibia,¹⁻³ and inhibited knee extension.¹ Therefore, the tension in the graft should replicate the tension in the intact ACL.^{15,21}

Tension in the graft replicates the intact ACL when the tension is negligible except when the knee reaches maximum hyperextension and hyperflexion.^{15,16} The tension pattern of the ACL graft replicates the intact ACL; when the tibial and femoral tunnels are placed without PCL and roof impingement, the femoral tunnel is drilled through the tibial tunnel, and the back wall of the femoral tunnel is 1 mm thick.^{12,21}

We prefer to use the Size-Specific Femoral Aimer (Arthrotek, Inc.) to place the femoral tunnel. The size of the femoral aimer is selected to match a diameter of the femoral tunnel. The offset of the femoral aimer is designed to leave a back wall to the tunnel that is 1 mm thick (Fig. 5). Removal of the ACL remnant with an angle curette allows the femoral aimer to rest directly on bone instead of soft tissue, which prevents blowout of the back-wall.¹⁰ The tip of the femoral aimer is inserted through the tibial tunnel and into the over-the-top position and positioned on bone. The femoral aimer is rotated externally and angulated laterally away from the PCL. The guidewire is drilled through the femoral aimer and the reamer is drilled over the guidewire. The use of this transtibial technique, in which the femoral tunnel is placed and drilled through a correctly placed tibial tun-

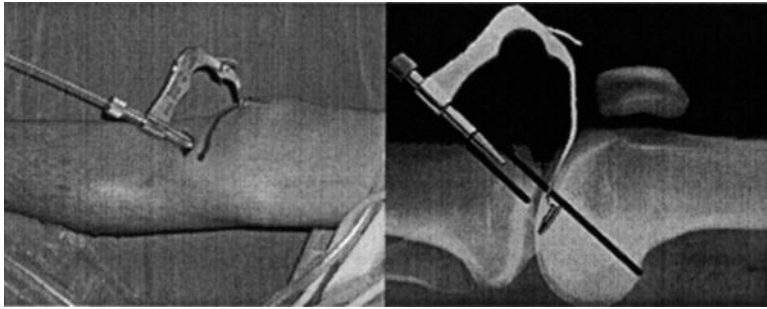


FIG. 4. The tip of the guide is positioned inside the notch with the bump facing the intercondylar roof. The knee is placed in maximum hyperextension, the handle of the guide is lifted to lock the guide in place, and the guide pin is drilled through the lateral hole in the bullet, which places the guide pin 5 to 6 mm posterior and parallel to the intercondylar roof in the sagittal plane.

nel, results in the tension pattern of the graft replicating the tension pattern of the intact ACL.²¹

SURGICAL TECHNIQUE

The surgical technique for placing the tibial and femoral tunnels without PCL impingement, without roof impingement, and with the tension pattern of the intact ACL can be viewed online (http://www.drstevehowell.com/ezloc_video.cfm).

Portal Placement

Place the medial portal at the medial edge of the patellar tendon. The medial portal is used for inserting the tibial guide, and the placement of the medial portal at the medial edge of the patellar tendon is necessary so that the guide centers in the notch. Place the lateral portal through the lateral third of the patellar tendon. The use of the arthroscope through the transpatellar lateral portal allows a clear view up of the femoral tunnel.

Assess a Widen Notch

Remove the remnant of the torn ACL so that the lateral edge of the PCL and the posterior edge of intercondylar roof are clearly seen. Insert the Howell 65 Degree Tibial Guide through the medial portal. Use the 9.5 mm wide tip on the guide to gauge the space between the PCL and lateral femoral condyle. Perform a wall-

plasty using the angled osteotome until the space between the PCL and lateral femoral condyle exceeds the diameter of the graft by 1 mm (Fig. 2).

Tibial Tunnel Placement

Reinsert the tibial guide through the medial portal and position the tip of the guide inside the notch with the bump facing the intercondylar roof. Visualize the bump on the guide while the knee is positioned into maximum hyperextension to be sure that the bump of the guide remains positioned inside the notch. From the lateral side of the knee, insert the alignment rod through the proximal hole in the handle of the guide. Orient the alignment rod parallel to the tibial joint line and perpendicular to the long axis of the tibia, which positions the guide so that the tibial tunnel is drilled at the angle of 65° with the medial tibial joint line in the coronal plane (Fig. 3). Drill the guidewire through the lateral hole of the bullet. The guidewire should enter the notch midway between the PCL and lateral femoral condyle (Fig. 6). Drill the tibial tunnel with use of a full-fluted cannulated reamer that matches the diameter of the graft.

Check for Posterior Cruciate Ligament and Roof Impingement

To check for PCL impingement, flex the knee and insert the impingement rod through the tibial tunnel and into the notch. The correct placement of the impingement

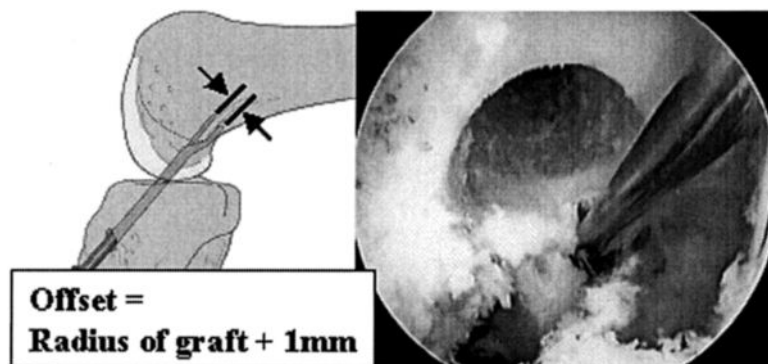


FIG. 5. The tip of femoral aimer is inserted through the tibial tunnel and into the over-the-top position, and rested directly on bone. The guidewire is drilled through the femoral aimer. The femoral tunnel is drilled through the anterolateral cortex of the femur with use of a cannulated 1-inch reamer. The offset of the femoral aimer is designed so that the back wall of the femoral tunnel is only 1 mm thick.

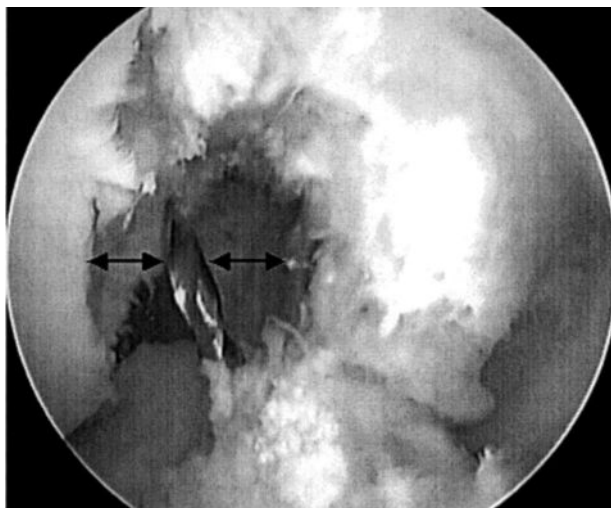


FIG. 6. The tibial guidewire is drilled through the lateral hole of the tibia with use of Howell 65 Degree Tibial Guide, whereas the knee is positioned into maximum hyperextension. The guidewire should pass midway between the lateral femoral condyle and posterior cruciate ligament (PCL) to avoid PCL impingement. If the guide wire passes more medially over the base of the PCL, then the graft will be subjected to PCL impingement.

rod is between the lateral femoral condyle and the PCL, pointing down the sidewall of the notch. The lateral edge of impingement rod should pass through the apex of the lateral tibial spine (Fig. 7).

To check for roof impingement, place the knee in



FIG. 7. To avoid posterior cruciate ligament (PCL) impingement, the impingement rod should pass between the lateral femoral condyle and the PCL and the tip of the impingement rod and form a triangle with the PCL. The impingement rod should point down the sidewall of the notch, the lateral edge of the impingement rod should pass through the apex of the lateral tibial spine, and the medial edge of the impingement rod should cross only a few fibers at the insertion of the PCL.

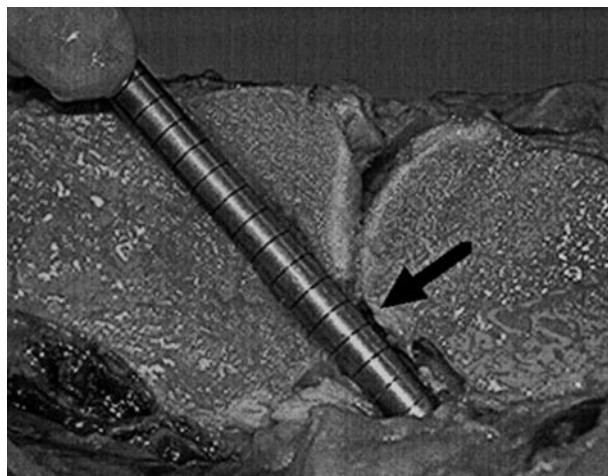


FIG. 8. This sagittal, cutaway view of the cadaver knee in maximum hyperextension shows the use of the impingement rod to check for roof impingement. The anterior cruciate ligament graft is placed without roof impingement when the knee is maximum hyperextension and an impingement rod; the same diameter of the graft passes freely into the notch through the tibial tunnel. There should be 1 to 2 mm of clearance between the intercondylar roof and impingement rod (arrow). Notice that placing the knee in maximum hyperextension prevents the relationship between the roof and graft from being seen with an arthroscope. The clinical consequence of not being able to “see” is that roof impingement can go undetected and untreated even by the experienced knee surgeon.

maximum hyperextension and insert the impingement rod through the tibial tunnel and into the notch. Free passage of the impingement rod indicates avoidance of roof impingement (Fig. 8).

Femoral Tunnel Placement

Remove the remnant of the ACL origin from the over-the-top position with the angled curette.¹⁰ Removing the remnant of the ACL allows the tip of the Size-Specific Femoral Aimer to rest directly on bone instead of soft tissue, which prevents blowout of the posterior wall of the femoral tunnel. Insert the femoral aimer through the tibial tunnel and into the notch. Slightly extend the knee, insert the tip of the femoral aimer into the over-the-top position, and let the knee flex to lock the aimer in place. Externally rotate and laterally angulate the femoral aimer away from the PCL. Drill the guidewire through the lateral femoral cortex. The placement of the guidewire is correct when the guidewire is lateral to the PCL and pointing down the sidewall of the notch. Drill the femoral tunnel with a 1-inch cannulated femoral reamer (Arthrotek, Inc.) that matches the diameter of the graft. The 1-inch reamer does not touch the PCL when the tibial and femoral tunnels are correctly placed without PCL impingement. Confirm the back wall of the femoral tunnel is 1 mm thick (Fig. 5).

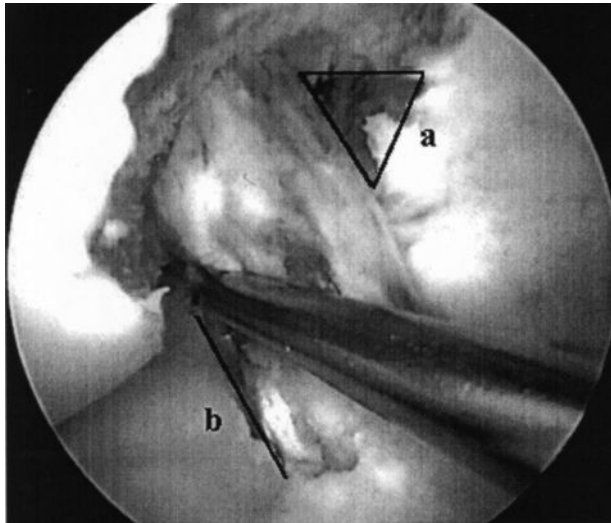


FIG. 9. The anterior cruciate ligament (ACL) graft is placed without posterior cruciate ligament (PCL) impingement when there is a triangular space between the ACL graft and the PCL (A) and when the lateral wall of the tibial tunnel passes through the apex of the lateral tibial spine (B). Notice that a wallplasty is required to accommodate the ACL graft, which is wider than the spindle-shaped intact ACL. The use of a wallplasty allows the entrance of the tibial tunnel to be shifted lateral away from the base of the PCL, which allows the lateral wall of the tibial tunnel to pass through the tip of the lateral tibial spine.

Insert and Fix the Anterior Cruciate Ligament Graft

Insert and fix the ACL graft in the femur and tibia using the appropriate fixation technique. We prefer to fix the graft in the femur with the EZLoc and in the tibia with the WasherLoc and Bone Dowel (Arthrotek). The rationale and surgical techniques for the EZLoc, WasherLoc, and Bone Dowel are also described in this issue of the journal.^{17,18}

Assess Anterior Cruciate Ligament Graft Position and Tension

Look for the triangle formed by the ACL graft and PCL, which indicates that the graft will not impinge against the PCL during knee flexion (Fig. 9). Palpate the tension in the graft with a probe and view the tension in the graft during a Lachman test.

CONCLUSION

The correct tunnel placement requires avoidance of PCL impingement, avoidance of roof impingement, and replication of the tension pattern of the intact ACL. For correct tunnel placement, in the coronal plane, the tibial tunnel should form an angle of 60° to 65° with the medial joint line, and the lateral edge of the tibial tunnel should

pass through the apex of the lateral tibial spine. In the sagittal plane, the tibial tunnel should be 5 to 6 mm posterior and parallel to the intercondylar roof with the knee in maximum hyperextension. Correct placement of the tibial tunnel is the most important step in the transtibial technique because both the correct femoral tunnel placement and the replication of the tension pattern of the intact ACL are automatic.

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