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14 Avoiding ACL Graft Impingement: Principles for Tunnel Placement Using the Transtibial Tunnel Technique

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INDICATIONS/CONTRAINDICATIONS

The transtibial tunnel technique in which the femoral tunnel is drilled through the tibial tunnel is a common technique for tunnel placement. This technique can be used regardless of the type of graft material and fixation. The transtibial technique can be used in all patients requiring a primary anterior cruciate ligament (ACL) reconstruction both acute and chronic, revision ACL surgery, and ACL reconstruction in the setting of the multi-ligament knee injury. There are no absolute contraindications to use of the transtibial tunnel technique for ACL reconstruction. Correct tunnel placement for ACL reconstruction is imperative to the success of the procedure. Graft sources, fixation methods, and rehabilitation cannot overcome the adverse consequences of poor tunnel placement.

There are three criteria of correctly placed tibial and femoral tunnels for ACL reconstruction:(a) the avoidance of roof impingement, (b) avoidance of posterior cruciate ligament (PCL) impingement, and (c) the establishment of the tensile behavior in the ACL graft similar to the native ACL. All three criteria are required for a successful ACL reconstruction.

Roof impingement occurs when the ACL graft prematurely makes contact with the intercondylar roof of the notch before the knee reaches terminal extension, which causes loss of extension and anterior laxity. The cause of roof impingement is positioning the tibial tunnel too anterior in the sagittal plane.

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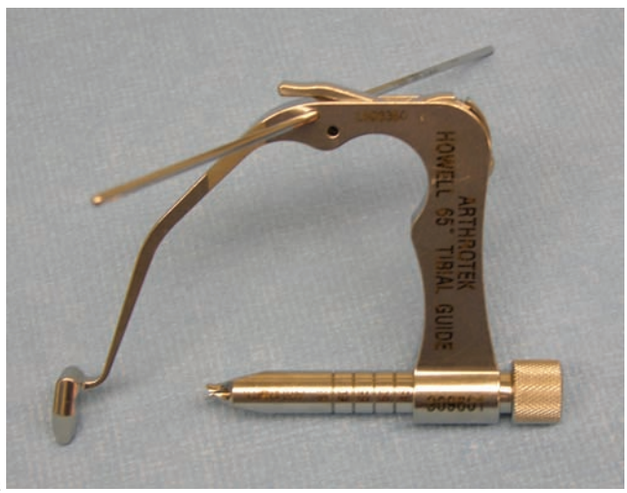
PCL impingement occurs when the ACL graft makes contact with the leading edge of the PCL before the knee reaches terminal flexion, which causes loss of flexion and anterior laxity. The cause of PCL impingement in the transtibial technique is positioning the tibial tunnel too vertical and medial in the coronal plane.

Finally, correct femoral tunnel position in both the sagittal and coronal planes is required to establish the tensile behavior in the ACL graft similar to the native ACL. Because the femoral tunnel is drilled through the tibial tunnel using size-specific aimers, the position of the tibial tunnel determines the position of the femoral tunnel with the transtibial technique. Therefore, the tibial tunnel sets up the position of the femoral tunnel, which means that the key tunnel in the transtibial tunnel technique is the tibial tunnel.

PREOPERATIVE PLANNING

Once the decision has been made by the patient to undergo surgical treatment of the ACL deficient knee, the surgeon must decide on the technique for placing the tunnels, graft choice, and fixation. All tunnel placement techniques including the transtibial, transportal, and two-incision technique can be used with any type of graft and fixation. Scientific studies by a variety of authors support the use of the transtibial tunnel technique and the use of the 65-degree tibial guide (Arthrotek, Warsaw, IN) that references the intercondylar roof with the knee in full extension for placing the tibial tunnel (Fig. 14-1).



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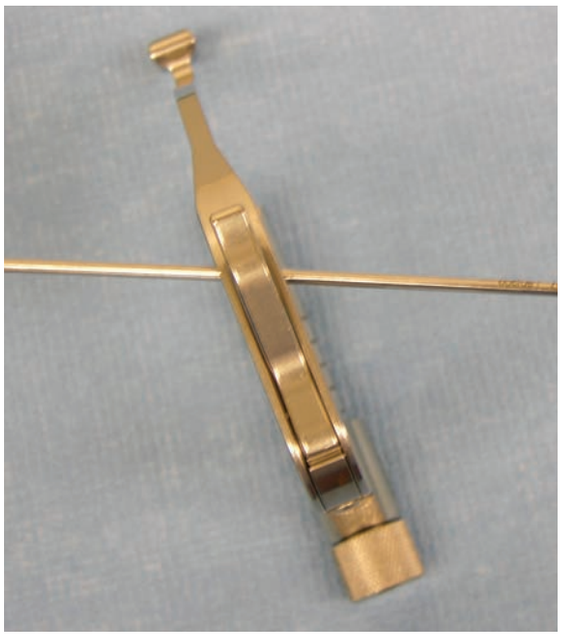

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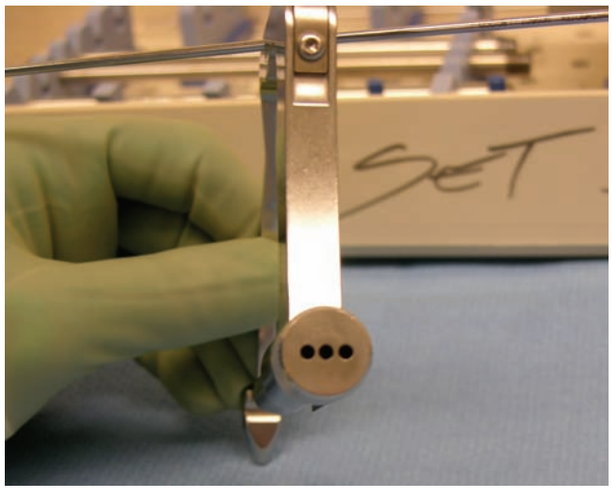

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FIGURE 14-1

A: Lateral view of 65-degree tibial guide with coronal alignment rod. **B:** Superior view of 65-degree tibial guide with coronal alignment rod. **C:** Axial view of 65-degree tibial guide demonstrating bullet with multiple holes for guidewire placement.

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An advantage of the transtibial technique with the 65-degree tibial guide is that the tunnel placement is accurate and customized without the need for tedious preoperative planning or time-consuming intraoperative imaging. Customization begins with the use of the 9.5-mm wide tip of the 65-degree tibial guide to gauge the width of the space between the lateral edge of the PCL and the lateral femoral condyle. Generally, the space between the PCL and the lateral femoral condyle is substantially smaller than the width of the ACL graft. The portion of the notch allocated to the ACL graft varies among patients as evidenced by some notches being narrower than others, and by the cross-sectional area of some notches being dominated by the PCL, leaving little room for the ACL graft. We advocate widening the notch by removing bone from the medial edge of the lateral femoral condyle (i.e., wallplasty) until the space between the PCL and lateral femoral condyle exceeds the width of the ACL graft by 1 mm. Since most grafts range from 8 to 10 mm, the free insertion of the 9.5-mm wide tip of the guide between the PCL and lateral femoral condyle indicates that the notch is sufficiently wide. Customizing the width of the notch to accommodate the width of the ACL minimizes PCL impingement by moving the tibial tunnel, femoral tunnel, and ACL graft lateral away from the PCL, which minimizes PCL impingement improving flexion and anterior stability.

A second step of customization is that the 65-degree tibial guide accounts for the anatomic variability in the angle of the intercondylar roof and knee extension that exists between patients and consistently positions the tibial tunnel in the posterior half of the native ACL tibial footprint and avoids roof impingement without a roofplasty. The roof angle (23–60 degrees) and knee extension (-2–30 degrees) both vary widely among patients. The correlation between the two is weak, so that patients with the same roof angle often have a different knee extension and patients with the same knee extension often have a different roof angle. Surgeons need to account for these two independent variables simultaneously. By drilling the tibial tunnel with the knee in full extension while referencing the intercondylar roof with the 65-degree tibial guide, the sagittal placement of the tibial tunnel has simultaneously accounted for the patient's unique combination of roof angle and knee extension. Magnetic resonance imaging studies have demonstrated the native ACL is located posterior and parallel to the intercondylar roof with the knee in terminal extension. The tibial tunnel is positioned posterior and parallel to the intercondylar roof and prevents roof impingement of the ACL graft without performing a roofplasty, which improves knee extension and anterior stability.

A third step of customization is that the 65-degree tibial guide incorporates the use of a coronal alignment rod, which improves the accuracy of setting the angle of the tibial tunnel in the coronal plane, further minimizing the risk of PCL impingement. Setting the angle of the tibial tunnel at 65 $\pm$ 5 degrees in the coronal plane avoids PCL impingement. The use the transtibial technique and a tibial tunnel at 65 $\pm$ 5 degrees in the coronal plane positions the femoral tunnel so that the tensile behavior of the ACL graft is similar to the native ACL while improving knee flexion and anterior stability.

The last step in customization is the use of size-specific femoral aimers through a tibial tunnel placed to create a femoral tunnel with a 1-mm back-wall for any diameter ACL graft. The use of the size-specific femoral aimers in a knee in which the notch has been sufficiently widened, without roof impingement and without PCL impingement, ensures correct placement of the femoral tunnel. The remnants of the ACL origin in the over-the-top position must be removed so that the femoral aimer rests on bone. Resting the femoral aimer directly on bone creates a femoral tunnel with a thin 1-mm back-wall and eliminates "blowingout" the posterior wall of the femoral tunnel. Therefore, the advantage of the transtibial technique is that the surgeon needs to focus on the meticulous placement of only one tunnel, the tibial tunnel, reducing the error associated by placing the femoral and tibial tunnels independently.

For surgeons, choosing to use a point-and-shoot guide, preoperative lateral radiographs taken with the knee in full extension, helps determine the intercondylar roof angles and knee extension and aids them intraoperatively when positioning the tibial tunnel in the sagittal plane. Surgeons must estimate coronal plane positioning with these guides since there are no coronal alignment devices on these guides. The standard is to use intraoperative fluoroscopy to check the position of the tibial guidewire in both the sagittal and coronal planes before drilling the tibial tunnel.

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SURGERY

Patient Positioning

Position the patient supine on the operating table. After induction of anesthesia, perform an examination under anesthesia. Place a tourniquet around the proximal thigh of the operative leg. Position the operative leg in a standard knee arthroscopy leg holder with the foot of the operating table flexed completely. Alternatively, surgeons may decide to use a lateral post instead of a leg holder. Position the contralateral leg in a gynecologic leg holder with the hip flexed and abducted with mild external rotation. Ensure there is no pressure on the peroneal nerve and calf (Fig. 14-2). Alternatively, surgeons can position the operative leg flexed over the side of the table using a lateral post and maintaining the contralateral leg extended on the operating table.

Technique

After sterile prep and drape, exsanguinate the leg and inflate the tourniquet. Establish inferolateral and inferomedial portals touching the edges of the patella tendon starting 1 cm distal to the inferior pole of the patella. Alternatively, a transpatellar inferolateral portal can be used with a medical portal placed along the medial border of the patella tendon (Fig. 14-3). The medial portal must touch the edge of the patella tendon because if it is placed more medial, the tibial guide may not stay seated in the intercondylar notch with the knee in full extension. An optional outflow portal can be established superiorly.

Perform a diagnostic arthroscopy. Treat meniscal or articular cartilage injuries. Identify and remove the torn remnant ACL stump (Fig. 14-4). It is not necessary to denude the tibial insertion of the native ACL tissue. In fact, retaining the insertion of the native ACL helps seal the edges of the ACL graft at the joint line and does not result in roof impingement if the tibial tunnel has been appropriately positioned. Remove the synovium and soft tissue in the notch to expose the lateral edge of the PCL (Fig. 14-5). Remove any of the ACL origin from the over-the-top position using an angled curette and shaver (Fig. 14-6).

FIGURE 14-2
Patient set-up.

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FIGURE 14-3
Portal placement for use of 65-degree tibial guide.

Insert the tibial guide through the medial portal. Advance the guide into the intercondylar notch (Fig. 14-7). The tip of the guide is 9.5-mm wide. If the guide makes contact and deforms the PCL as it enters the intercondylar notch, perform a lateral wallplasty. Remove bone in 1- to 2-mm wide slivers from the lateral wall until the tip of the guide passes into the notch without deforming the PCL, which creates a wide enough area for an 8- to 10-mm wide graft (Fig. 14-8). Do not remove any bone from the intercondylar roof since the roof anatomy is crucial for proper positioning of the tibial guide-pin in the sagittal plane using the 65-degree tibial guide (Fig. 14-9). Remove the lateral wallplasty fragments (Fig. 14-10).

Insert the 65-degree tibial guide through the anteromedial portal that touches the medial edge of the patella tendon into the intercondylar notch between the PCL and lateral femoral condyle to ensure adequate width of the notch for the ACL graft (Fig. 14-11). Fully extend the knee. Visualize that the tip of the guide is captured inside the notch and that the arm of the 65-degree tibial guide contacts the trochlea groove (Fig. 14-12). Place the heel of the patient on a Mayo stand to maintain

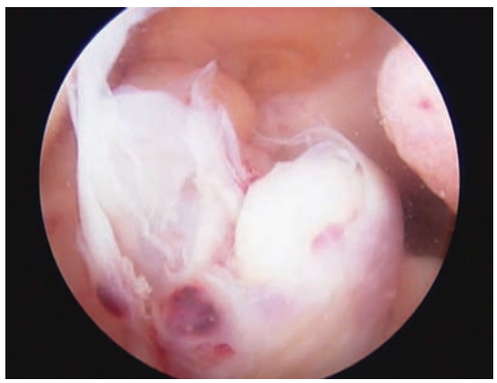

FIGURE 14-4
Torn ACL stump.

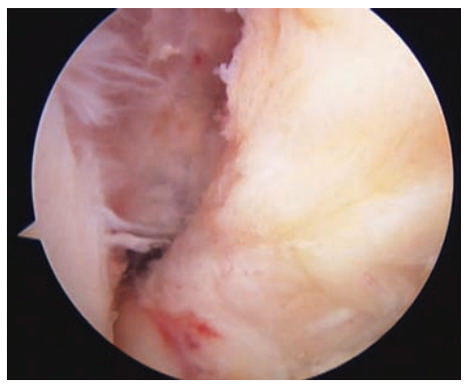

FIGURE 14-5
Identify the leading superior border of the PCL.

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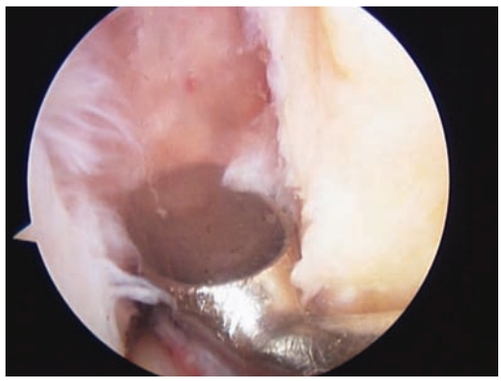


FIGURE 14-6

Clean the over-the-top position using an angled curette.

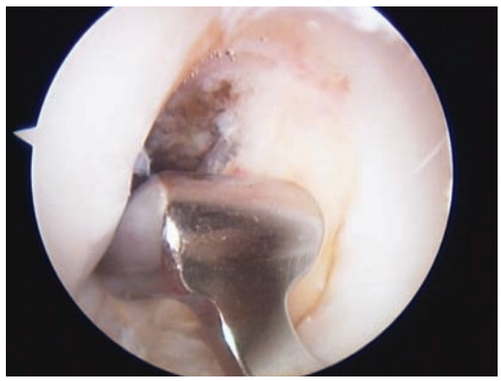
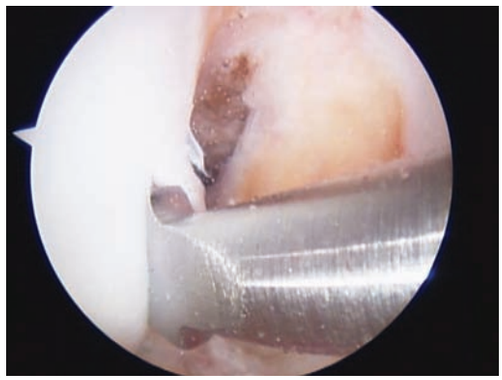


FIGURE 14-7

The 9.5-mm wide tip of the 65-degree tibial guide demonstrates notch stenosis with deformation of PCL.



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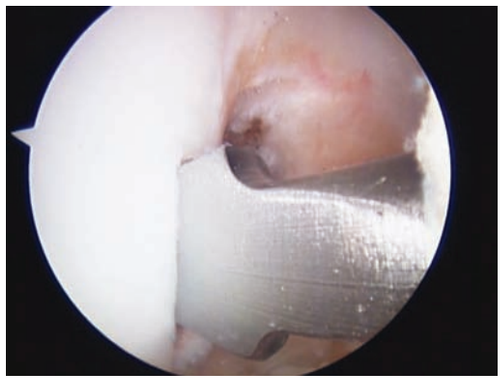

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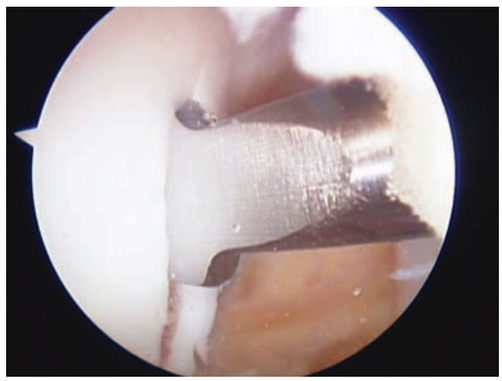

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FIGURE 14-8

A–C: Lateral wallplasty performed using angled osteotome.

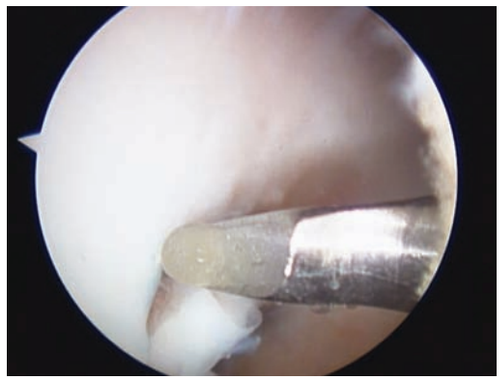

FIGURE 14-9

Angled osteotome prevents extension of wallplasty into roof of intercondylar notch.

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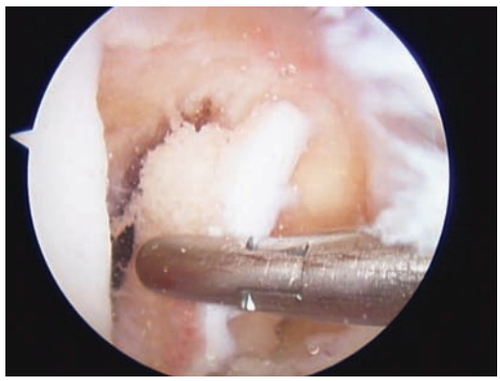


FIGURE 14-10
Removal of lateral wallplasty fragments.

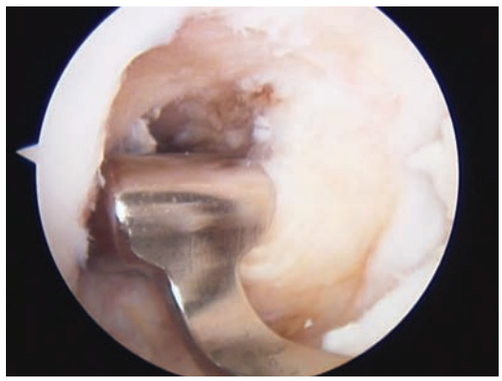
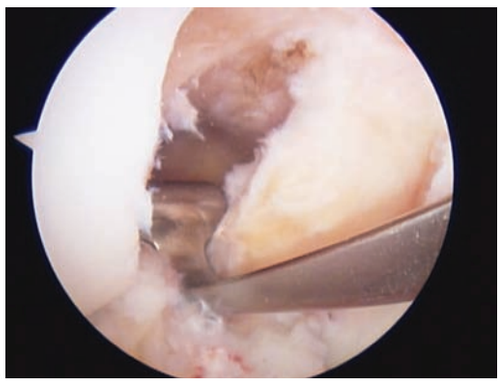


FIGURE 14-11
65-degree tibial guide tip ensures adequate notch width.

the knee in maximum hyperextension. Stand on the lateral side of the leg and insert the coronal alignment rod through the proximal hole in the guide. Rotate the 65-degree guide in varus and valgus until the coronal alignment rod is parallel to the joint and perpendicular to the long axis of the tibia (Fig. 14-13). Insert the combination bullet guide/hole changer into the 65-degree guide and advance the bullet until seated against the anteromedial cortex of the tibia. Drill the tibial guide-pin through the lateral hole in the bullet until it strikes the guide intra-articularly (see Fig 14-13). Remove the bullet from the tibial guide and remove the guide from the notch. Tap the guide-pin into the notch and assess its position.



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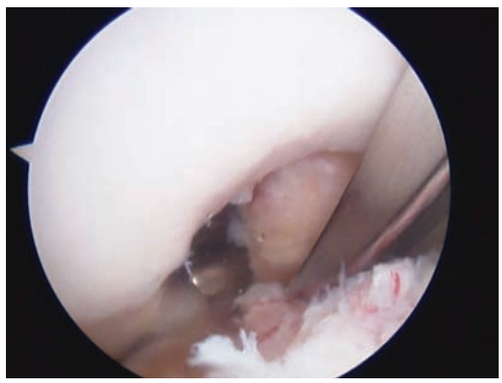

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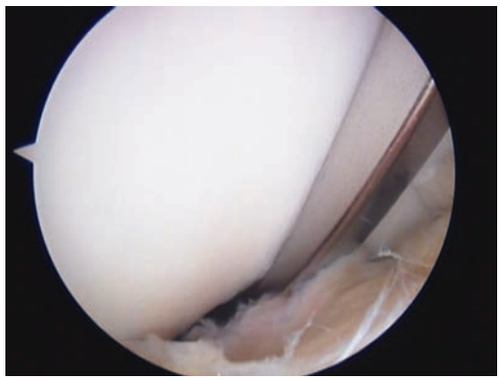

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FIGURE 14-12
A: 65-degree tibial guide tip positioned in the intercondylar notch. **B:** Extend the knee maintaining 65-degree tibial guide tip in the intercondylar notch. **C:** Position of the 65-degree tibial guide arm against the trochlea groove with the knee in terminal extension.

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A

B

FIGURE 14-13

A: Tibial guide wire drilled through lateral hole in bullet with the knee in full extension and coronal alignment rod positioned parallel to the knee joint. **B:** Lateral view.

The tibial guide-pin is properly positioned in the coronal plane when it enters the notch midway between the lateral edge of the PCL and the lateral femoral condyle. The guide-pin should not touch the PCL (Fig. 14-14). The tibial guide-pin is properly positioned in the sagittal plane when there is 2- to 3-mm of space between the guide-pin and intercondylar roof with the knee in full extension. The space can be assessed by manipulating a 2-mm wide nerve hook probe between the between the guide-pin and intercondylar roof in the fully extended knee.

Prepare the tibial tunnel. Ream the tibial cortex with a reamer with the same diameter as the prepared ACL graft. Harvest a bone dowel from the tibial tunnel by inserting an 8-mm in diameter bone dowel harvester and centering rod over the tibial guide-pin. Use a mallet and drive the bone dowel harvester until it reaches the subchondral bone (Fig. 14-15). Remove the dowel harvester with cancellous bone dowel (Fig. 14-16). If the tibial guide-pin is removed with the bone dowel, then replace it by inserting it through an 8-mm reamer that has been reinserted into the tunnel created by the bone dowel harvester. Ream the remainder of the tibial tunnel with the appropriate diameter reamer.

Check for PCL impingement by placing the knee in 90 degrees of flexion and inserting the impingement rod into the notch. A triangular space at the apex of the notch and no contact at the base of the notch between the PCL and impingement rod confirms the absence of PCL impingement (Fig. 14-17). Check for roof impingement by placing the knee in full extension and inserting an impinge-

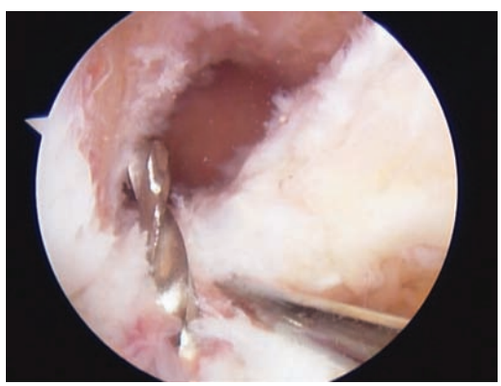

FIGURE 14-14

Guide pin position in the intercondylar notch.

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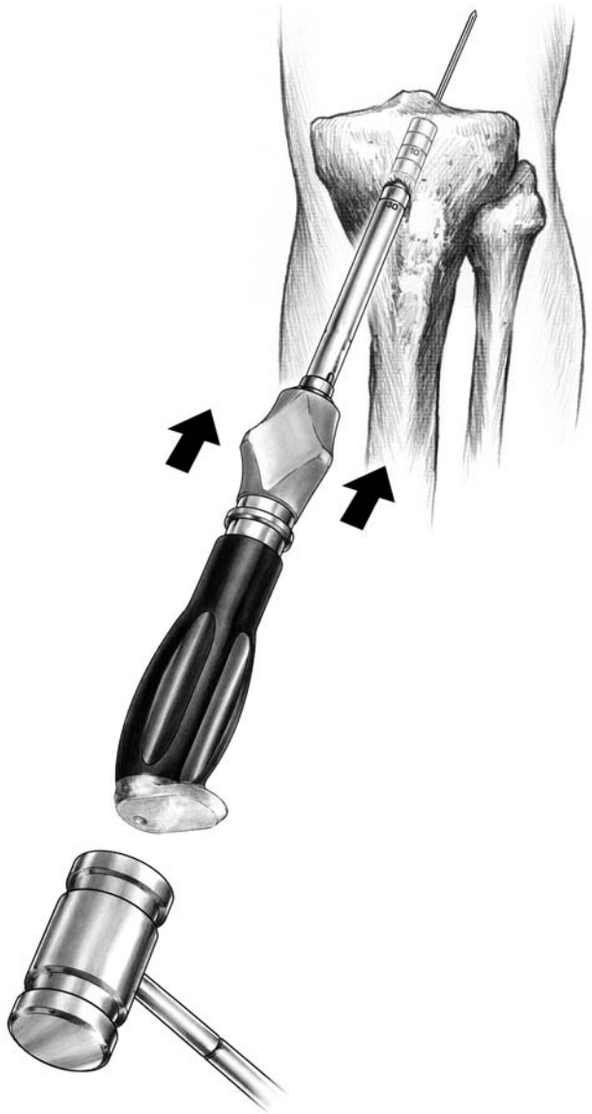

FIGURE 14-15
Impact bone dowel harvester over guide pin.

ment rod the same diameter as the tibial tunnel into the intercondylar notch (Fig. 14-18). Free pistoning of the impingement rod in and out of the notch with the knee in full extension confirms the absence of roof impingement.

Place the femoral tunnel using the transtibial technique. Insert the size-specific femoral aimer through the tibial tunnel with the knee in flexion. The size of the "off-set" of the femoral aimer is based on the diameter of the ACL graft and is designed to create a femoral tunnel with a 1-mm backwall. Extend the knee and hook the tip of the femoral aimer in the over-the-top position. Allow gravity to flex the knee until the femoral guide seats on the femur. Rotate the femoral aimer a quarter turn lateral away from the PCL, which positions the femoral guide-pin farther down the lateral wall of the notch minimizing PCL impingement (Fig. 14-19). Drill a pilot hole in the femur through the aimer and remove both the guide-pin and femoral aimer.

Redirect the femoral guide-pin to shorten the femoral tunnel from 35 to 50 mm in length with use of the following technique. Reinsert the femoral guide-pin into the pilot hole and flex the knee to 90

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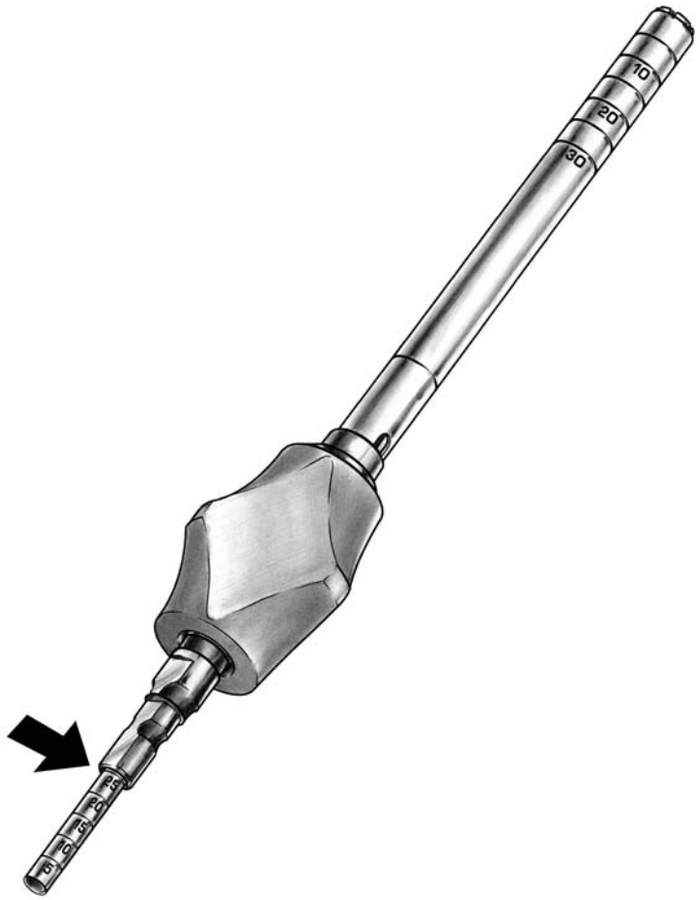

FIGURE 14-16
Remove harvester with cancellous graft inside of harvester tube.

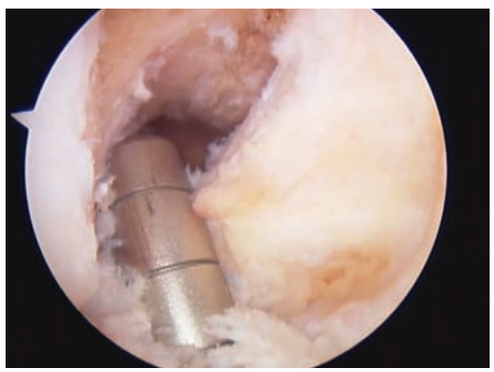

FIGURE 14-17
Impingement rod in notch.

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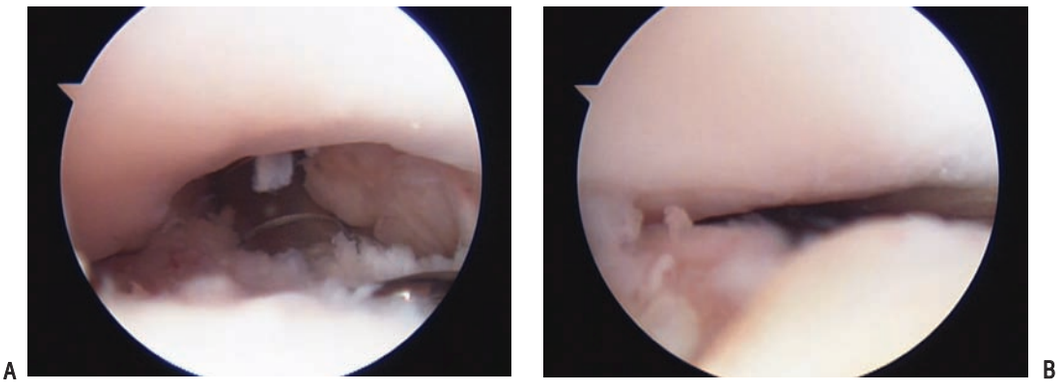

FIGURE 14-18

A: Extend knee and assess for roof impingement. **B:** Roof impingement not seen with knee in full extension.

to 100 degrees. Drill the guide-pin through the anterolateral femoral cortex. Pass a cannulated 1 in. reamer the same diameter as the ACL graft over the guide-pin. Ream the femoral tunnel. Confirm the back-wall of the femoral aimer is only 1 mm thick (Fig. 14-20). Confirm the center of the femoral tunnel is midway between the apex and base of the lateral half of the notch (Fig. 14-21). A femoral tunnel placed correctly down the sidewall does not allow room for a second posterolateral tunnel.

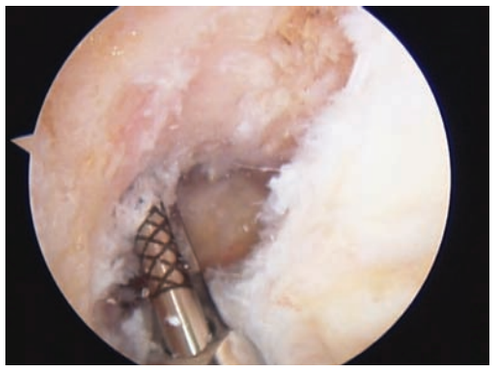

FIGURE 14-19

Femoral guide pin position using femoral aimer through tibial tunnel.

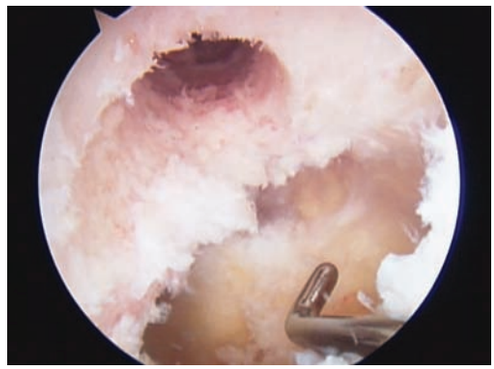

FIGURE 14-20

Back wall thickness of femoral tunnel.

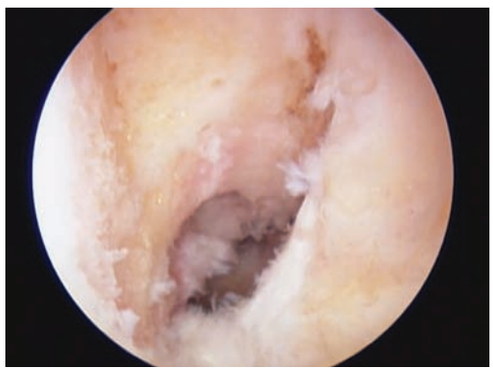

FIGURE 14-21

Femoral tunnel position assessed through lateral portal.

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Pearls and Pitfalls

Proper use of the 65-degree tibial guide minimizes the complications of impingement associated with tunnel placement for ACL reconstruction surgery. Pitfalls typically stem from improper use of the 65-degree tibial guide. First, it is important not to alter the anatomy of the intercondylar roof when performing the lateral wallplasty should a wallplasty be required. A significant roofplasty at the time of wallplasty can change the sagittal plane position of the tibial tunnel. In revision cases where the intercondylar notch anatomy may be distorted, the use of intraoperative fluoroscopy or radiography may help to further ensure satisfactory tunnel position (Fig. 14-22). A second pitfall is improper position of the medial portal. The 65-degree tibial guide requires medial portal placement adjacent to the medial border of the patella tendon to ensure the 65-degree tibial guide seats centrally in the intercondylar notch with the knee in full extension. Too medial placement of the medial portal will position the 65-degree tibial guide medial in the notch. Too medial placement of the tibial tunnel in the notch using the transtibial tunnel technique will result in PCL impingement of the graft. Finally, it is important to clean the over-the-top position using the angled curette. Because the sized-specific femoral aimers position the femoral tunnel with only a 1- to 2-mm thick posterior wall, any soft tissue remaining in the over-the-top position will lead to further posterior positioning of the femoral tunnel with possible blowout of the posterior wall.

POSTOPERATIVE MANAGEMENT

Postoperative management of ACL reconstruction depends on (a) the use of slippage resistance, stiffness, and strength of the femoral and tibial fixation devices; (b) placement of the tibial and femoral tunnels so that roof impingement is prevented, PCL impingement is prevented, and the tension pattern in the ACL graft matches the tension of the native ACL; and (c) the rapidity of tendon-tunnel healing. Brace-free, self-administered, aggressive rehabilitation of an impingement-free graft is safe when slippage resistant, high strength and high stiffness fixation devices are used. Placing the ACL graft without roof and PCL impingement eliminates the concern that the graft might be injured by knee extension and flexion exercises. The addition of the bone dowel in the tibial tunnel eliminates tunnel widening, increases stiffness, and snugs the fit in the tunnel, which speeds tendon-tunnel healing.

COMPLICATIONS

Poor tibial and femoral tunnel placement causes catastrophic complications, including loss of extension and anterior instability from roof impingement and loss of flexion and anterior instability from PCL impingement. Because there are few salvage options available to improve the success of ACL reconstruction in the setting of poorly placed tibial and femoral tunnels, prevention is the best treatment for avoiding complications associated with poor ACL tunnel placement. In the case of loss of extension in a stable knee caused by mild roof impingement, a roofplasty may help regain extension and reduce injury to the ACL graft from abrasion against the roof. Loss of flexion due to PCL impingement is not treatable unless the ACL graft is removed. The use of cross-pin fixation devices, not widening the notch, and the drilling of the femoral tunnel through the anteromedial portal, all tend to place the femoral tunnel too vertical causing PCL impingement and a loss of knee flexion and increased instability.

When using a transtibial tunnel technique, the 65-degree tibial guide prevents impingement complications associated with poor tunnel placement by allowing surgeons to consistently customize sagittal plane position of the tibial tunnel for all patients regardless of the differences in roof angle anatomy and knee extension. The use of a coronal alignment rod with the 65-degree tibial guide improves the accuracy of tibial tunnel position in the coronal plane, thereby effectively avoiding PCL impingement and improving rotational stability of the knee. The femoral tunnel position is automatic with the transtibial tunnel technique. Therefore, consistent anatomic placement of tibial tunnel in both the sagittal and coronal planes avoiding both roof and PCL impingement results in proper femoral tunnel placement that establishes graft tension behavior similar to the native ACL and increases the long-term success of ACL reconstruction (Fig. 14-23).

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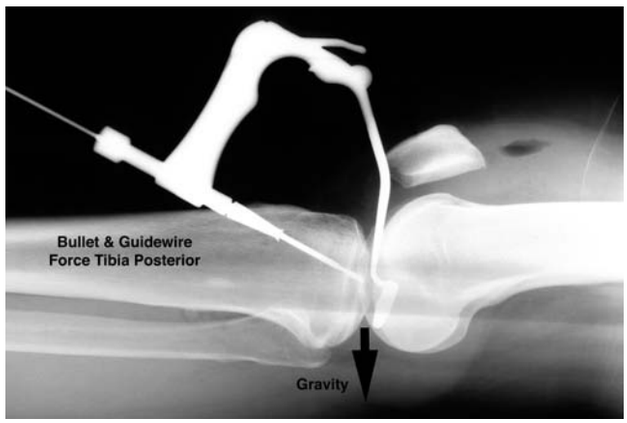

FIGURE 14-22

Lateral radiograph with knee in full extension demonstrating knee joint and guide pin position with the 65-degree tibial guide in place.

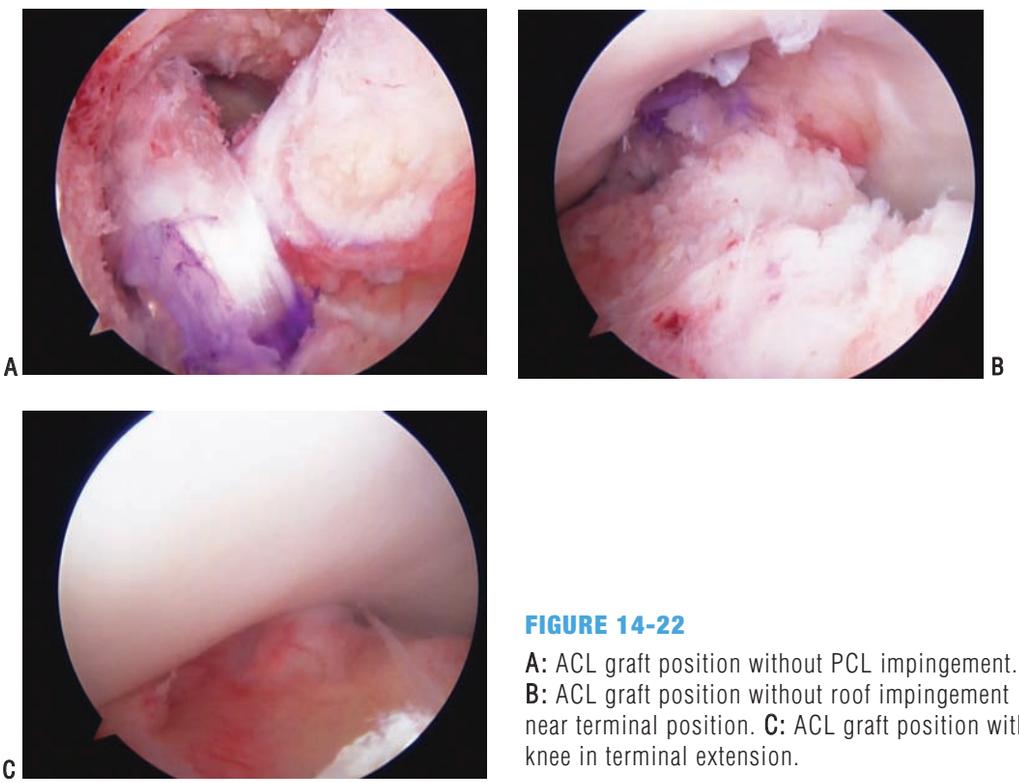

FIGURE 14-22

A: ACL graft position without PCL impingement. **B:** ACL graft position without roof impingement near terminal position. **C:** ACL graft position with knee in terminal extension.

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RESULTS

The use of the 65-degree tibial guide with coronal alignment rod increases the accuracy of tibial tunnel placement in both the sagittal and coronal planes. The increased accuracy of tibial tunnel placement avoids the complications of graft impingement leading to better knee range of motion and stability. In addition, because the 65-degree tibial guide was designed to reference the patient's anatomy, a roofplasty is not required when the guide is properly used. Minimizing the notchplasty required to position an impingement-free graft decreases the amount of graft pre-tensioning required to stabilize the ACL-deficient knee and is favorable for graft remodeling and long-term function.

RECOMMENDED READING

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