

Revision Anterior Cruciate Ligament Reconstruction With Patellar Tendon Allograft

Surgical Technique

R. Alexander Creighton, MD and Bernard R. Bach, Jr., MD

Abstract: Despite the marked advances in treatment and highly predictable success of anterior cruciate ligament (ACL) reconstruction, an approximate 10% to 15% failure rate is noted in the literature. The mechanism of failure is often difficult to ascertain and is often multifactorial. A strong patient-physician relationship must be established to proceed with revision ACL reconstruction. After the decision has been made to proceed with revision ACL reconstruction extensive preoperative planning is warranted. Revision ACL reconstructions are a “salvage” procedure to allow the patient to perform activities of daily living. A return to sports is a possibility, but the patient’s expectations should be realistic and individualized. This article focuses on the surgical technique of revision anterior cruciate ligament reconstruction with patellar tendon allograft.

Key Words: revision ACL, reconstruction, technique, patellar tendon allograft

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Reconstruction of the anterior cruciate ligament (ACL) is the sixth most common procedure performed by orthopedists, with more than 100,000 ACL reconstructions being performed annually in the United States.^{1,2} Despite the success of this procedure with good and excellent results ranging between 75% and 90%, there are failures.^{1–8} The definition of ACL failure in simple terms includes symptomatic instability, pain, extensor dysfunction, and arthrofibrosis.^{7,9–11} The purpose of this discussion is to focus on graft failure and recurrent instability. The mechanism of failure is often difficult to ascertain and can be multifactorial. Failures that occur within 6 months of reconstruction can be due to surgical technique, incomplete graft incorporation, and excessive rehabilitation or premature return to athletic competition. If the failure occurs after 1 year, then it is most likely due to trauma. Following primary ACL reconstruction, 8% of the time recurrent instability is caused by graft failure.^{12,13} These are the patients in which revision ACL reconstruction would benefit to eliminate symptomatic instability and may improve quality of life. A strong

patient–physician relationship must be established to proceed with revision ACL reconstruction. Revision ACL reconstructions are a “salvage” procedure to allow the patient to perform activities of daily living.^{14,15} Noyes¹⁶ reported a 27% failure rate with autograft and a 33% failure rate with allografts in revision ACL reconstruction. A return to sports is a possibility, but the patient’s expectations should be realistic and individualized. Uribe¹⁷ reported that only 54% returned to their preinjury level of activity.

After the decision has been made to proceed with revision ACL reconstruction extensive preoperative planning is warranted. Previous operative reports are obtained, patient expectations are reviewed, and discussion of a staged procedure is recommended. A staged procedure is recommended if tunnel expansion is greater than 1.5 cm, loss of motion is more than 10° of extension or 20° of flexion, or there is significant varus or valgus requiring an osteotomy.¹ Knee incisions should be meticulously planned, preferably using the previous incisions, and always maintaining a skin bridge of 7 cm.¹¹

Allografts or autografts can be used for revision ACL reconstruction. It is acceptable to use either, and the choice of the graft should be individualized. It is our preference at Rush University Medical Center to use non-irradiated patellar tendon allograft for revision ACL surgery.^{18,19} The advantages of allograft material are well documented. Allografts eliminate donor site morbidity, use smaller incisions, decrease operative time, reduce postoperative pain, and avoid the risk of patella fracture or additional anterior knee symptoms. Allografts provide the ability to customize bone blocks to fill expanded tunnels, and are available in many types and sizes.^{1,5,20–22} The disadvantages of allografts are possible disease transmission, slower biologic remodeling time, potential for a low level immune response, limited availability, and increased cost. The risk of disease transmission is most concerning for the patient and the surgeon and must be discussed in the informed consent. The estimated risk of disease transmission with allografts is approximately 1 in 1.6 million.² This risk has been reduced by improved standards and monitoring of the American Association of Tissue Banks (AATB) and the FDA. There has been one HIV case in 1985 and two cases of Hepatitis C, but there have been no reported cases of viral transmission since 1993 with the current guidelines.^{18,23} Improved procurement, including screening of the donor, harvesting within 24 hours, and quarantine of these tissues up to 4 months, is most likely responsible for the decreased risk of disease transmission. With

From the Division of Sports Medicine, Midwest Orthopaedics at Rush University Medical Center, Chicago, IL.
Reprints: Bernard R. Bach, Jr., MD, 1725 W. Harrison St., Suite 1063, Chicago, IL 60612 (e-mail: brbachmd@comcast.net).
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the use of polymerase chain reaction (PCR), the period of undiagnosed vulnerability is reduced from 6 months to 19 days. It is of the utmost importance for the surgeon to be familiar with a tissue bank with a proven track record and one that follows AATB guidelines, because not all allografts are processed or stored the same way. In evaluating the literature on allograft material, it is difficult to come to a firm conclusion because there is so much variability. One cannot stereotype allograft material because of differences in surgical technique, rehabilitation protocols, tissue processing, graft material used, patient populations, and variable outcome measurements. Clinical results using allograft material have been promising, despite the slower biologic incorporation rate.^{8,24} In the study of Harner and colleagues,²⁵ the allograft reconstructed group had better knee scores than the autograft reconstructed group, but this was not statistically significant. Noyes noted 89% good to excellent results using allografts in ACL reconstructions and had acceptable arthrometric results.²¹

PATIENT POSITIONING

The majority of our patients undergo general endotracheal anesthesia. A femoral nerve block can be added to aid in immediate postoperative pain control. The patient is placed in the supine position with the waist on the operating table flexed to reduce lumbar extension (Fig. 1). A thorough examination under anesthesia is performed, including Lachman, anterior and posterior drawer, varus/valgus, and pivot shift testing. Evaluation of external rotation and thigh-foot angles at 30° and 90° of flexion is done to assess for posterolateral instability. Findings are compared with the contralateral knee.

The operative leg is placed in the leg holder with a tourniquet on the upper thigh. Do not inflate the tourniquet unless bleeding obstructs visualization. It is essential to be able to flex the knee 110° to facilitate femoral screw placement.



FIGURE 1. Patient positioning is demonstrated. The non-surgical leg is placed in a GYN holder. The surgical leg is positioned to allow 110° to 120° of knee flexion. The waist and foot of the table are flexed. Reprinted with permission.³

The contralateral leg is placed in a padded foot holder with the hip and knee slightly flexed to prevent common peroneal nerve or femoral nerve palsy. The leg is then prepped and draped. All previous incisions and portals are noted and marked. Make sure your allograft is available and that fluoroscopy is accessible in case previously placed hardware needs to be removed prior to the initiation of anesthesia.

DIAGNOSTIC ARTHROSCOPY

For diagnostic arthroscopy, a superomedial or superolateral portal for outflow is established. An inferolateral portal is used for arthroscope placement and an inferomedial portal is established as a working portal. Thorough assessment of the patellofemoral joint, medial and lateral gutters, associated chondral lesions, evaluation and treatment of meniscal pathology, and critical attention is paid to the intercondylar notch and tunnel placements.²

NOTCH PREPARATION AND NOTCHPLASTY

Remnant soft-tissue is debrided to improve visualization. The remaining ACL graft tissue is debrided with a combination of arthroscopic scissors, arthroscopic osteotome, arthroscopic electrocautery, and a motorized 5.5 mm full-radius resector. If a synthetic graft was used this can be an intensive process. In a revision surgery, significant notch variability or stenosis can be encountered, but 20–22 mm of width at the mid-tunnel region is necessary to avoid graft impingement. All soft tissue is removed from the lateral wall of the intercondylar notch posteriorly to the “over the top” (OTT) position.

The notchplasty is performed with the use of a quarter-inch curved osteotome and a 5.5 mm spherical burr, moving from anterior to posterior and from apex to inferior making sure to avoid misinterpreting a vertical ridge two-thirds posteriorly as the true posterior outlet. The goals of the notchplasty are to allow visualization of the entire lateral wall and OTT position, and to prevent graft impingement with the knee in full extension. A probe is used to palpate the OTT position to confirm the appropriate position.

The previous femoral tunnel position is carefully assessed, making sure to remove soft tissue and identify, if possible, the previously placed interference screw (Fig. 2). Bony overgrowth is removed to reduce the possibility of stripping the screw during removal. A spinal needle is used for triangulation, and an accessory inferior medial portal is established. A 14-inch-hyperflex nitinol pin is placed through this portal and advanced into the screw. It may be necessary to hyperflex the knee so that a screwdriver can be inserted into the screw recess. The screw is carefully removed (Fig. 3). If the screw head is stripped, or becomes stripped, commercially available extraction devices are available. If the femoral tunnel has been placed vertically, which is currently the most common technical error (in contrast to anteriorly placed femoral or tibial tunnels with the dual incision technique), an alternative to screw removal is screw advancement. By further inserting the screw the medial wall is maintained, which obviates the need for bone grafting.

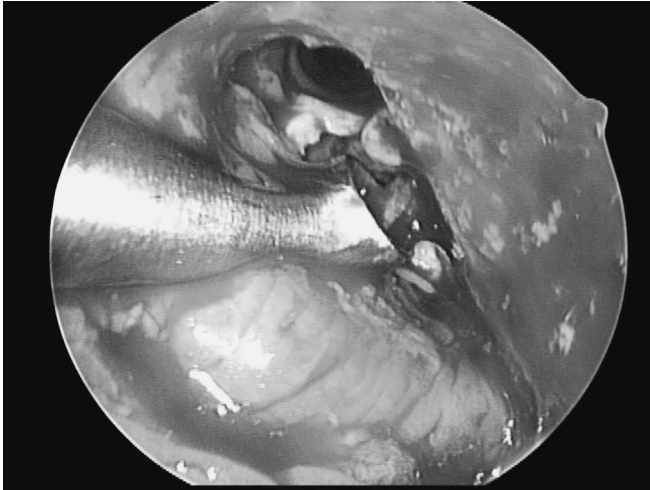


FIGURE 2. The previous femoral tunnel is identified. Note that the index femoral screw has been removed.

TIBIAL TUNNEL

If the tunnel is in acceptable position, the tibial screw is removed so the tunnel may be reused (Fig. 4). The screw can be left in place if it will not be in the path of the new tunnel. Using the previous incision, a medially based rectangular periosteal flap is created just medial to the tibial tubercle and proximal to the pes anserinus tendons. A tibial aiming device is placed through the inferomedial portal or an accessory portal in the midpatellar region that is inferior to the inferomedial portal. Allografts frequently require this accessory portal.

The variable angle tibial guide is set between 50° and 55°. This should be at least 25 mm below the joint line, superior to the insertion of the pes anserinus tendons, and directed toward the femoral anatomic attachment site (FAAS). The guide is positioned in the sagittal plane using the posterior edge of the anterior horn of the lateral meniscus because the exit site for the pin that will be drilled. The guide should be

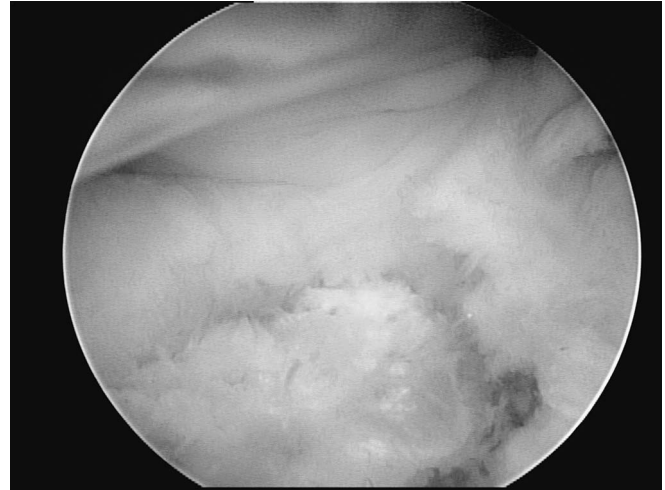


FIGURE 4. The former tibial tunnel with footprint debrided is shown.

centrally placed to allow passage of the graft between the PCL and the lateral wall of the notch. It should be approximately 7 mm anterior to the PCL. The guide pin is drilled through the guide, and is arthroscopically verified that it is posterior (3–5 mm) to the intercondylar notch with the knee extended.

This tunnel may be confluent with the primary ACL reconstruction's initial tunnel. If a completely new hole can be drilled with the graft in the ideal position, this is preferred. A mallet or drill is used to slightly insert the guide wire into the intercondylar roof to stabilize it during cannulated reaming (Fig. 5). The pin is overreamed with an 11-mm cannulated reamer. The posterior and posterolateral tunnel is contoured on the articular side of the tibia with a chamfer reamer, and the intraarticular edges are smoothed with a rasp. Make absolutely certain that this entrance is clear.

Once the tibial tunnel is drilled, one can slide the arthroscope retrograde to inspect for residual adherent soft

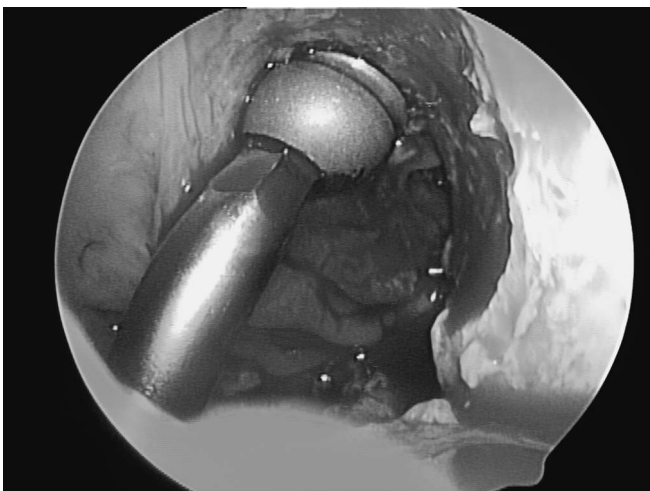


FIGURE 3. The previous femoral tunnel screw is removed in another example.

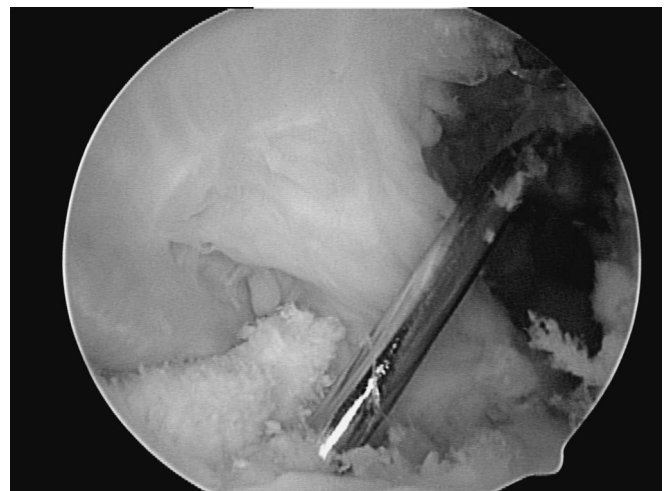


FIGURE 5. The tibial pin placement is drilled and the tibial aiming device removed in this left knee.

tissue from the index reconstruction. One can also determine if there is overlapping or intratunnel expansion that may require bone grafting (Fig. 6A–D). Matchstick-shaped bone graft can be fashioned from the unused allograft bone plugs to fill the cancellous void.

FEMORAL TUNNEL

The goal of femoral tunnel placement is to prepare a tunnel that originates at the 1-o'clock position in the left knee and the 11-o'clock position in the right knee and has a 1–2 mm posterior cortical shell. This provides for a near anatomic/isometric position of the graft. If the primary femoral tunnel is in the ideal position, it may be reused. If the intra-articular opening is in good position, a diverging tunnel may be used (Fig. 7). If the primary tunnel is anterior, which is most often the case, then the hardware is left in place and a new tunnel is drilled posteriorly. If the tunnel has to be expanded further posterior, resulting in an enlarged tunnel, then one can again use a larger bone plug or stacked interference screws. If the posterior wall is deficient, conversion to a two-incision technique is recommended to obtain secure fixation. Alterna-

tively, an endobutton with possible aperture fixation could be considered (Fig. 8).

Soft tissue is meticulously cleared from the OTT position and the position is confirmed with a probe. With the pump turned off and the knee “dry”, the 7-mm femoral offset guide is placed through the tibial tunnel to the OTT position. The orientation of the tibial tunnel impacts the ability to correctly place the femoral aimer. Some surgeons place the femoral aimer through an accessory portal and hyperflex the knee to create the femoral tunnel. The guide allows for a 1–2-mm thin posterior cortical rim following reaming. If a 10-mm tunnel is desired, a 7-mm offset guide is used to leave 2-mm of posterior wall intact after reaming. The guide must be oriented toward the 1-o'clock (left) or 11-o'clock (right) positions. A probe is used to retract the PCL out of way while performing this step. The guide pin is drilled through the femoral offset guide to a depth of 3–4 cm. There may be a different tactile sense as one drills and subsequently reams, because the previously placed bone plug will be healed within the tunnel and will be more difficult to drill and ream. The pin is overdrilled with the selected reamer (when using a patellar tendon graft, a 10-mm reamer is used); the length of the tunnel

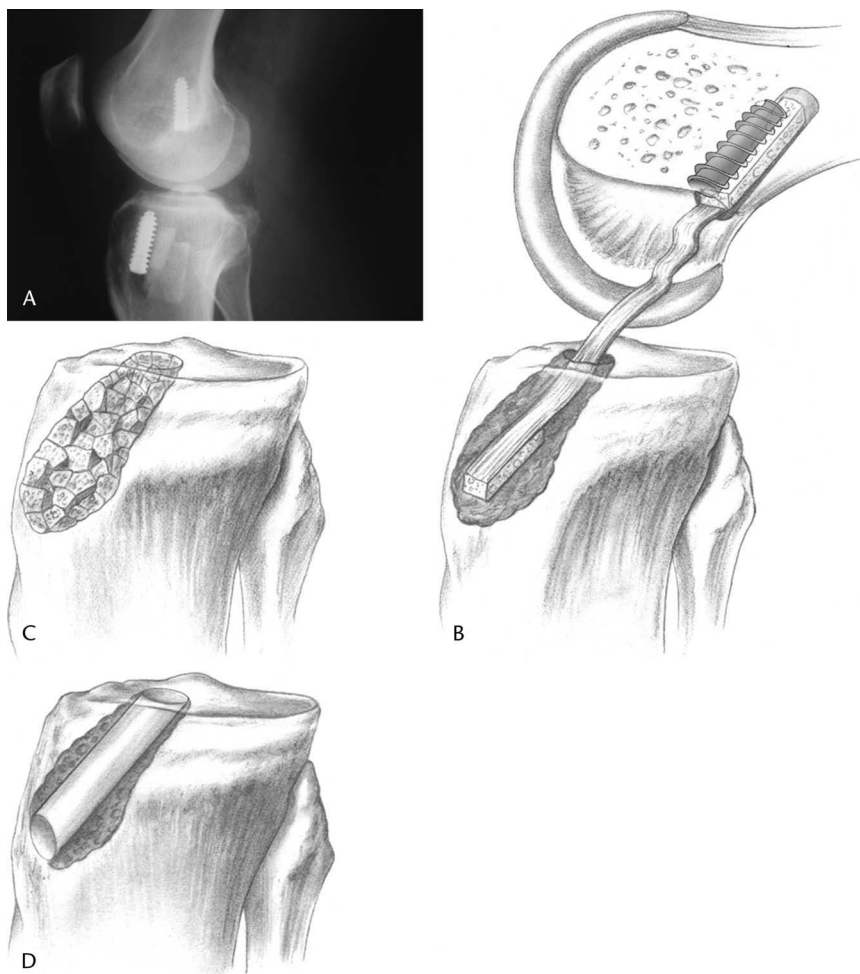


FIGURE 6. Filling of the tibial tunnel may be necessary, or staged bone grafting may be necessary. A, demonstrates a staged tibial tunnel which was grafted and then reused. B, shows an expanded tibial tunnel. C, depicts grafting of this tunnel. D, shows the revision tibial tunnel after the graft has consolidated. Reprinted with permission.³

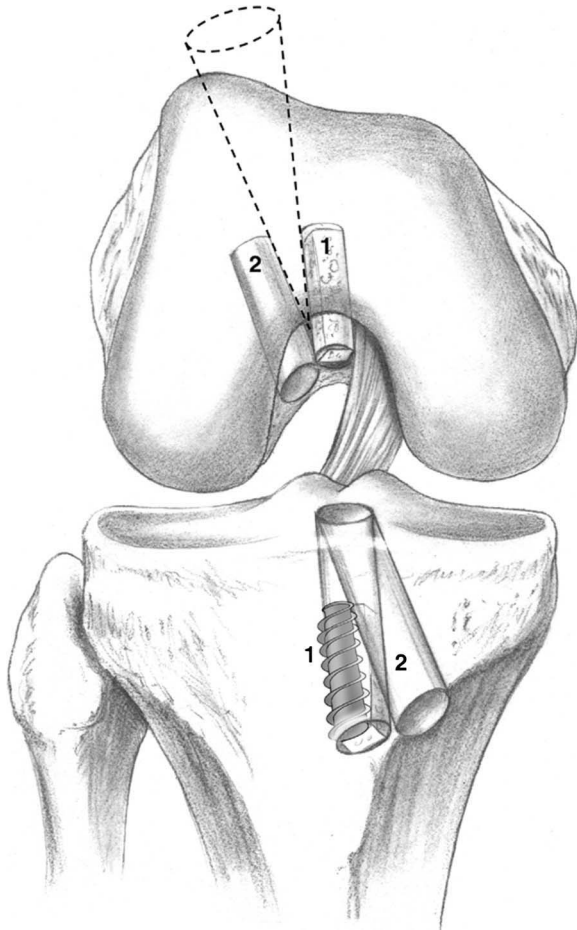


FIGURE 7. Concept of diverging femoral tunnel is depicted. The initial femoral tunnel ("1") is too central. Reprinted with permission.³

should be 5–8 mm longer than the length of the femoral bone plug to allow for possibly recessing the bone plug. An “endoscopic footprint” is created by reaming to a depth of 5–7 mm. The reamer is backed out and a probe is used to check the status of the posterior wall. If the posterior wall is intact, reaming is completed to the desired depth. If the index procedure’s screw is encountered, it will have to be removed if the reamer will not slide by the screw. Excess bone debris is removed by extracting the reamer from the hole while still rotating forward and by placing the shaver up the tibial tunnel into the femoral tunnel while copiously irrigating the knee.

The final notchplasty is completed and the entrance site of the femoral tunnel is smoothed. The femoral tunnel should appear circular at the entrance. Smoothing the anterior edge of the tunnel facilitates graft placement. The arthroscope is placed up the tibial tunnel and rotated 360° to visualize the entire tunnel to confirm that the posterior wall is intact and to determine if any soft tissue from the previous procedure requires debridement (Fig. 9).

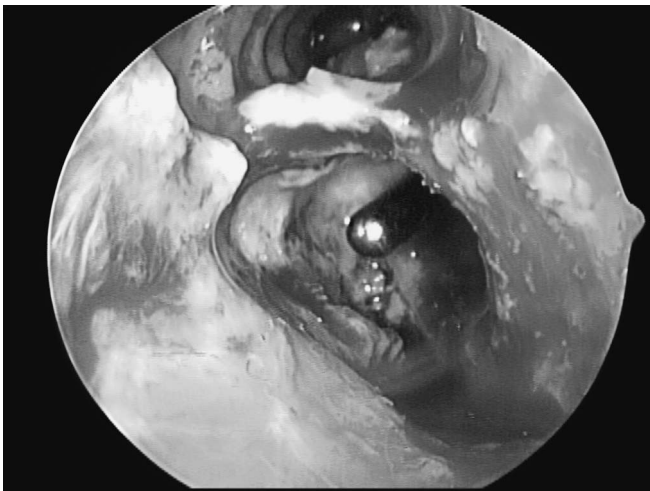


FIGURE 8. A new femoral tunnel is created by 2-incision technique.

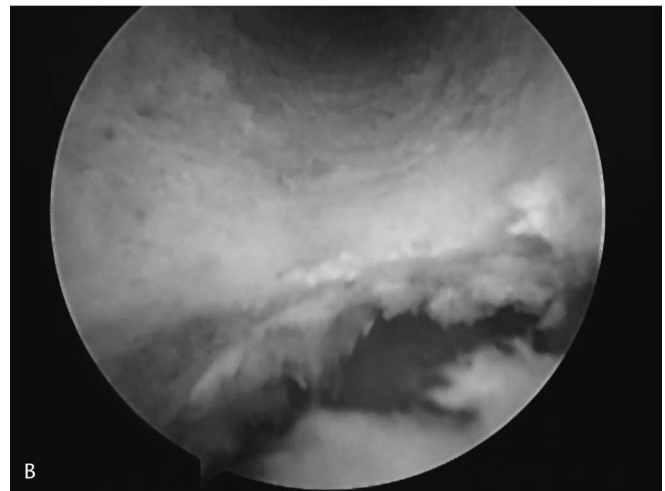
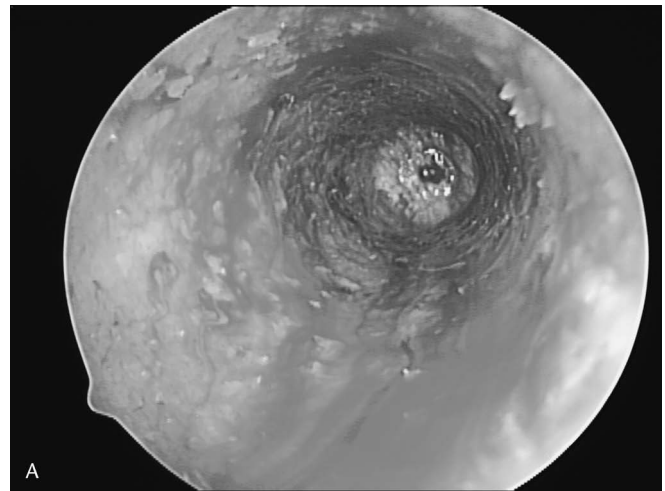


FIGURE 9. (A, B) An intact posterior wall of the femoral tunnel is arthroscopically demonstrated. Note the thin 1–2-mm cortical rim.

GRAFT PREPARATION AND PLACEMENT

The allograft is thawed by soaking it in normal saline at room temperature (Fig. 10). Excess fat pad and soft tissue is removed from the graft. The graft construct length is measured (95–105 mm), as the length of the soft tissue affects the angle selected on the tibial aiming device. “N + 10 mm” is generally sufficient to reduce significant graft construct mismatch; this is a modification of Miller’s “N + 7 mm” rule whenever the tibial tunnel drill angle equals the length of the soft tissue component of the graft plus 10. For example, if the soft tissue measures 45 mm, the selected drill angle is $45 + 10$ or 55° . The bone plugs are contoured to fit easily through a 10-mm sizer tube. If the tunnels are enlarged, the bone plugs can be kept larger to fill the defect.

The femoral bone plug-tendon interface is marked on the cancellous surface with a sterile marking pen. This step helps determine complete seating of the bone plug in the femoral tunnel. Two to three 2-mm holes are drilled through the tibial bone plug parallel to the cortical and cancellous surfaces. A #5 braided polyester suture is passed through each hole (Fig. 11). No suture is necessary in the femoral bone plug because a “push-in” rather than “pull-through” technique is used.

The push-in technique orients the cancellous surface of the plugs anteriorly with the tendinous/cortical portion posterior for the femoral tunnel. The longer bone plug (without sutures) is pushed up the tibial tunnel with a two-pronged pusher into the intercondylar notch area with the knee flexed 80° to 90° . A small curved hemostat placed through the inferomedial portal is used to grasp the graft at the junction of the proximal and middle portion of the femoral plug to guide the plug into the femoral socket. The bone plug is pushed nearly flush to the femoral surface entrance. The graft is left 3–5 mm in the joint to act as a skid for placement of the guide pin, which is positioned with the knee hyperflexed (Fig. 12). The pin is placed anterior to the bone plug until it bottoms out within the femoral tunnel. The bone plug is advanced flush to the articular entrance and is held in position while checking for graft construct mismatch at the tibial site. Prior placement of a pen mark at the bone tendon junction helps to confirm that the bone plug is completely seated.



FIGURE 10. Achilles tendon and patellar tendon allografts are two commonly used grafts for revision ACL surgery. Reprinted with permission.³

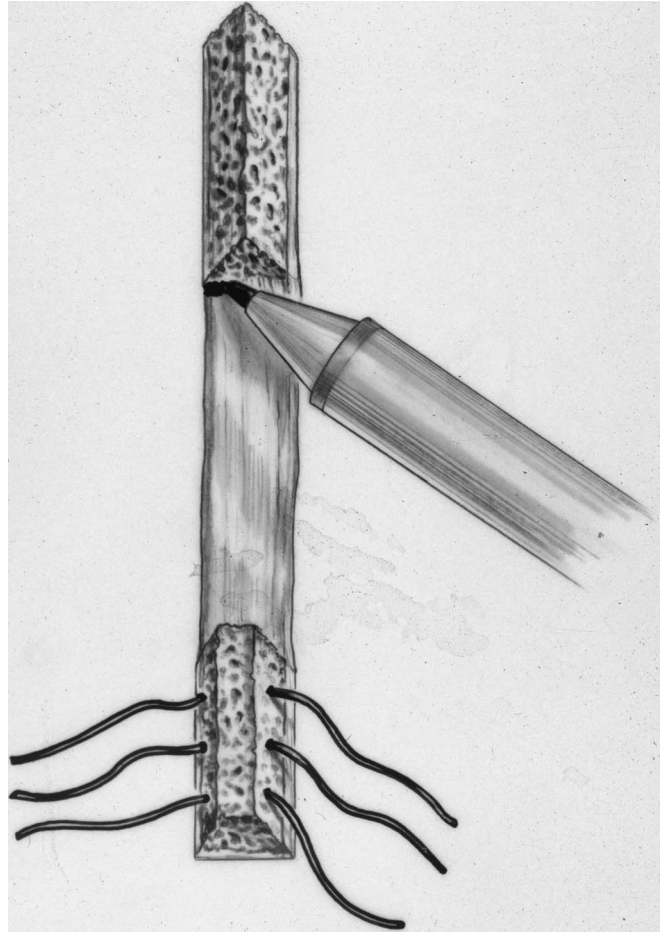


FIGURE 11. This schematic illustration depicts a prepared graft. Reprinted with permission.³

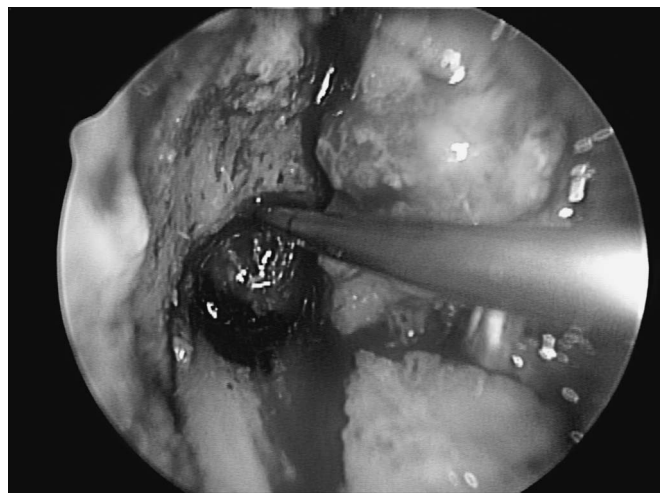


FIGURE 12. The femoral bone plug is left initially slightly prominent within the joint to act as a skid for the guide wire.

FEMORAL FIXATION

Document that the femoral bone plug is fully seated with a probe. A cannulated interference screw (7×25 mm) is placed through the inferomedial or accessory portal and visualized arthroscopically. Hyperflexion of the knee to 110° to 120° is maintained and the screw inserted (Fig. 13). The graft soft tissue is observed for rotation or twisting as the screw is inserted. Failure to hyperflex the knee can cause screw breakout through the posterior femoral cortex, non-parallel screw/graft placement, or graft laceration.

TIBIAL FIXATION

The knee is cycled through a full range of motion noting the movement of the tibial bone plug within its tunnel. While cycling the knee 90° to full extension the graft should shorten 1–2 mm during the final 20° to 30° of full extension (“gross isometry test”). The graft is generally rotated 180° , which places the tibial bone plug cortical surface anterior. The screw is placed on the cortex for better fixation. Anterior placement prevents wandering or divergence of the screw, which decreases fixation strength. Anterior screw placement will force the bone plug posteriorly in the tibial tunnel and if the screw tip extends beyond the tendo-osseous junction, it is less likely to injure the graft. The graft is stabilized with a hemostat to prevent twisting, and secured with a 9×20 mm cannulated metal interference screw (Fig. 14). This is performed with the knee extended and axially loaded.

If there is excess graft length and the tibial bone plug is protruding (“graft construct mismatch”) more than 40%, then one can rotate the graft up to 540° or perform a free bone block technique to address construct mismatch. The free bone block technique requires removal of the bone plug from the tibial side. A running baseball stitch suture is placed in the distal half of the tendon prior to placing it within the joint. The femoral side is placed back in the tunnel and secured with an interference screw. The free bone is placed back up the tibial tunnel



FIGURE 13. An intraoperative photograph of a femoral tunnel interference screw is demonstrated.

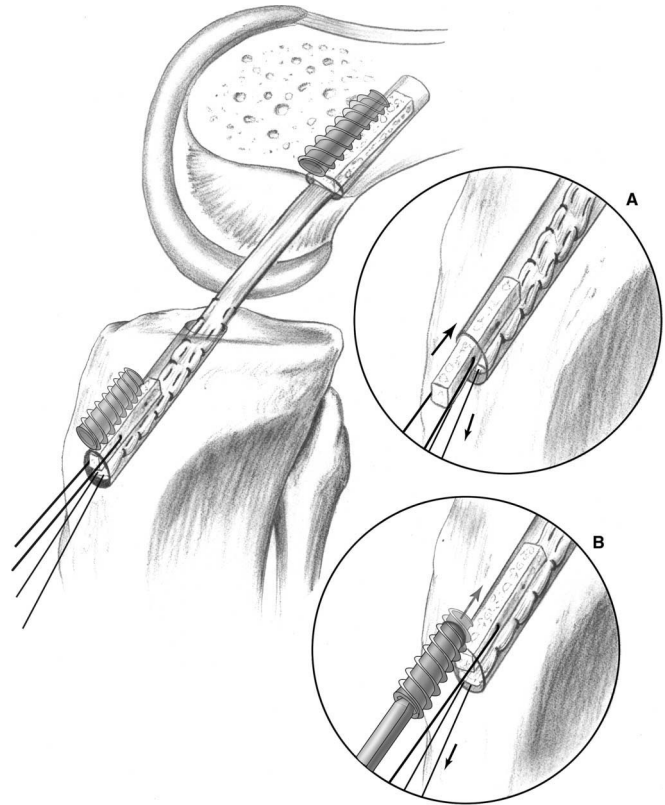


FIGURE 14. The concept of a “free bone block” modification used for a graft construct mismatch is shown. Reprinted with permission.³

and fixed against the tendon with an interference screw while maintaining tension on the graft via the intratendinous suture.

WOUND CLOSURE

If the tourniquet is used, it is deflated and hemostasis is obtained prior to closure. We use the tourniquet in fewer than 10% of our cases. The periosteal flap over the tibial tunnel and hardware is loosely approximated with No. 1 Vicryl. The subcutaneous layer is closed with No. 2 Vicryl. The skin is closed with a running subcuticular 3-0 Prolene and the portals are closed with a simple suture. The incisions, the deep tissues, and knee joint are injected with bupivacaine. Steristrips, gauze pads, and loose single Kerlix are placed over the wounds. A cryotherapy device and droplock brace in full extension are placed on the knee.

POSTOPERATIVE CARE AND REHABILITATION

Revision ACL reconstruction is performed on an outpatient basis. Oral pain medication and an intra-articular injection of a long acting local anesthetic such as bupivacaine are used. The addition of a femoral nerve block can also add postoperative pain relief. A cryotherapy device is applied immediately and used for 1 to 2 weeks. A brace is applied to protect the knee and maintain full extension, and progression of weight bearing is instituted (Fig. 15).



FIGURE 15. A droplock brace locked in full extension is applied to the knee at the conclusion of surgery.

If secure fixation is obtained operatively, rehabilitation is similar to a primary ACL reconstruction, but often should be individualized depending on the patient's cause of ACL failure.²⁶ It is also prudent to continue to remind the patient to limit their surgical expectations, because the goal is a functional, stable knee for everyday activities. Weight bearing is allowed as tolerated with the knee in full extension and in a hinged knee brace, and the patient should be weaned off crutches within the first week postoperatively. With the help of a physical therapist, an emphasis is placed on achieving full extension and equaling the opposite knee. Full flexion is usually achieved by 6 to 10 weeks. Also, quadriceps sets, straight leg raises, and prone hangs are initiated the first day. An official physical therapy program is initiated 5 to 7 days postoperatively. In general, bicycling is begun by 1 week, stair climbing machines at 4 to 6 weeks, light jogging at 12 weeks, and a gradual return to sports at 6 months. A custom ACL orthosis is worn for sports for the first year. Our results of revision ACL surgery with a nonirradiated graft are presented by Dr. Smith in this issue.

CONCLUSION

Revision ACL reconstruction surgery is a technically demanding procedure. Each revision presents its own set of challenges and intraoperative decisions. Success depends on a thorough preoperative evaluation of the patient's cause of failure, counseling the patient to limit their expectations of surgical outcome, surgical expertise, and individualized rehabilitation program. The choice of the graft for revision ACL reconstruction is individualized, but it is our preference to use a fresh-frozen nonirradiated bone patellar tendon bone allograft.

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