Techniques in Knee Surgery 3(4):251–258, 2004

TECHNIQUE

The Use of Quadriceps Tendon–Patellar Bone Autograft in Arthroscopic Two-Incision Anterior Cruciate Ligament Reconstruction

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■ ABSTRACT

Anterior cruciate ligaments (ACL) have been successfully reconstructed with a variety of techniques. The 2-incision technique is an accurate, versatile solution to both primary and complex revision ACL problems. Multiple grafts have been reported to yield good results, with the use of allograft tissue limited by cost and potential for disease transmission. The central quadriceps tendon should be considered for both primary and revision ligament surgery because of its size, strength, and low donor site morbidity.
Keywords: ACL, graft, quadriceps tendon, 2-incision technique

■ HISTORICAL PERSPECTIVE

Anterior cruciate ligament (ACL) reconstructions are performed at a rate of over 100,000 per year in the United States.[1] Historically, the bone–patellar tendon–bone has been the most popular graft source because of its strength and solid fixation with bone-to-bone healing within the tibial and femoral tunnels.[2,3] However, some are reluctant to use this graft because of the potential of postoperative patellofemoral pain with a reported incidence of 17%–56%.[4–7] Many surgeons have opted to use autogenous semitendinosus/gracilis tendons as an alternative graft option, with the number of the hamstrings tendon grafts performed approaching the use of bone–patellar tendon–bone autografts.

The 4-stranded ST/G graft has increased strength, stiffness, and cross-sectional area when compared with a 10-mm-wide patellar tendon graft.[2,3] However, concerns regarding the hamstring tendons include potential elongation of the graft postoperatively, less secure graft fixation, longer incorporation time into the bone tunnels, and unequal tensioning of the multiple strands. There are also conflicting studies regarding functional evaluation of hamstring muscle weakness after harvesting.[8,9] Hamstring tendon harvest induces atrophy of the tendon-dissected muscles.[10] Entire muscle–tendon units are harvested with hamstring sequestration, which may be counterproductive because the hamstrings act as dynamic restraints to anterior tibial translation.

Autogenous bone quadriceps tendon graft ACL reconstruction was originally described by Blauth in 1984.[11] Blauth's technique was further modified by Staubli with favorable clinical results published in 1990 and 1992.[12] A 10-mm-wide quadriceps tendon graft has a larger cross-sectional area and is stronger than a 10-mm-wide patellar tendon graft.[13] The quadriceps tendon–bone graft allows for secure fixation with an interference screw holding the bone plug within the femoral tunnel, and there are a variety of soft-tissue fixation options to secure the tendon in the tibial tunnel. This graft also has an advantage over the patellar tendon with regard to decreased donor site morbidity.[14,15] Because the quadriceps tendon can be harvested through a transverse incision at the proximal pole of the patella, the postoperative numbness seen with patella tendon grafts is not apparent. Furthermore, because the bone plug is taken from the proximal pole of the patella with the quadriceps tendon graft, neither the incision nor the donor site is under direct pressure with kneeling. Patients are less likely to complain of patellofemoral pain. The quadriceps tendon graft is also an option with revision cases when other grafts have already been used.

The 2-incision technique of ACL graft placement has been well described. Several authors have compared the single- versus 2-incision technique in ACL replacement with no significant difference with regard to clinical examination or functional overall outcome.[16,17] In 1999, Karlsson et al reported serious intraoperative complications in 4 cases when the 1-incision technique was used, in comparison to none with the 2-incision technique.[18]

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The 2-incision approach has advantages over the 1-incision procedure. It is a technique that should be in every ACL surgeon's arsenal, if not as the primary procedure, then as a salvage technique. Because the tibial and femoral tunnels are drilled independently, an accurate femoral tunnel can still be placed when a somewhat less than perfect tibial tunnel has already been drilled. We believe this technique makes it more difficult to place the femoral tunnel too far anterior. Although there are other methods to prevent graft/notch mismatch and to assess tunnel placement (ie, utilizing intraoperative imaging), the 2-incision technique allows for the use of a smoother through the tunnels, which decreases the chances of graft impingement.

When a femoral tunnel is drilled using the 1-incision transtibial technique, the femoral tunnel trajectory is dependent on the angle chosen for the tibial tunnel. In the 2-incision technique, the femoral tunnel trajectory is independent of the tibial tunnel. This flexibility is particularly useful for revision cases or when intraoperative problems arise with the placement of the femoral tunnel (ie, "posterior wall blowout") with the 1-incision technique. Because the tunnel trajectories can be independently modified extra-articularly with the 2-incision technique, longer tunnels can be placed to accommodate fixation of an allograft that is too long. Nevertheless, whichever technique is used, correct tunnel placement cannot be compromised without adversely affecting graft isometry and, ultimately, graft survivability.

■ INDICATIONS AND CONTRAINDICATIONS

Patient Selection

ACL reconstruction is indicated for people who want to remain more active than their knee will allow them after an ACL injury. Because a good result requires significant rehabilitation effort, patient selection is critical. Patients who have difficulty with the preoperative rehabilitation are likely to have postoperative compliance problems as well. Preoperatively, full extension equal to that of the contralateral leg is essential. In addition, the patient needs to demonstrate an arc of motion of approximately 0 to 120 degrees, perform a straight leg raise without loss of extension, and demonstrate good quadriceps control and circumference close to that of the contralateral extremity.[19,20] A dialogue regarding patient expectations needs to occur preoperatively.

Timing

Acute ACL tears are significant injuries associated with hemarthrosis, muscle spasms, and stiffness. It is prudent to rehabilitate the acute injury to achieve full extension, no swelling, and supple soft tissues before ACL reconstruction. A small effusion is acceptable. The preoperative rehabilitation helps predict the postoperative course.

■ PREOPERATIVE PLANNING

The diagnosis of an ACL tear is a clinical one, based on the history of injury and the physical examination findings, which include a positive Lachman and pivot shift test. The KT-1000 (Medtronics, San Diego, CA) is an instrumented test of anterior laxity that can be helpful in the evaluation of acute injuries when pain and muscle spasms make the examination more difficult. Plain x-rays are helpful to assess for fractures, physeal closure in young people, and arthrosis in older individuals. MRI can be useful in detecting associated bone bruises and injuries to the meniscus, articular surface, or to other structures. Although not required for ACL reconstruction, MRI is useful for preoperative planning and patient counseling about associated procedures such as meniscus repair.

■ TECHNIQUE

Positioning

The patient is positioned supine, and an examination under anesthesia to test stability and range of motion is performed on both the uninjured and injured extremities. The hips are flexed approximately 15 degrees, and a tourniquet is placed as proximal as possible on the thigh. A low-profile arthroscopic limb holder (A & S Machine, Hudson, WI) is secured around the midthigh. Ensure that the nonoperative extremity is adequately padded and protected. Check the nonoperative thigh muscle tension to prevent traction neurapraxia of the femoral nerve. The table end is fully flexed or removed to allow knee flexion past 90 degrees (Fig. 1). After a Betadine prep, 30 mL of 0.5% lidocaine with epinephrine and 5 mg of morphine is injected into the joint for preemptive analgesia and hemostasis. While the surgical team scrubs, the circulating nurse preps the limb with a Hibiclens scrub and DuraPrep. After draping, all portals and incisions are infiltrated with 1% lidocaine with epinephrine. It is our practice to flex the knee fully during exsanguination with an Esmarch bandage before inflating the tourniquet to ensure that the tourniquet does not tether the quadriceps tendon.

Diagnostic Arthroscopy

A diagnostic arthroscopy is then performed. Arthroscopic portals used include a superomedial for inflow and anteromedial and anterolateral working portals. It is important to make the anteromedial and anterolateral portals

FIGURE 1. Patient positioning with a low-profile limb holder. Note that the contralateral limb is abducted to facilitate posteromedial work if necessary.

as close as possible to the patellar tendon to allow easier access to the intercondylar notch (Fig. 2).

Notchplasty

Proper visualization of the intercondylar notch usually requires at least a minimal fat pad resection. A motorized shaver (5.5-mm aggressive shaver) is used to debride a portion of the anterior fat pad to provide better perspective and panoramic view of the entire intercondylar notch. Adequate fat pad resection should be completed before working within the notch. A 90-degree wand (Arthrocare, Sunnydale, CA) is used in coagulation mode to achieve fat pad hemostasis and in ablation mode to clear the tissue overlying the anterior roof of the notch and lateral edge of the PCL. A 10-mm curette is used to help estimate the notch size and need for roofplasty and/or notchplasty, to loosen soft tissue from the notch, and to find the over-the-top position. Bony notchplasty of the anterior roof and lateral wall is performed if necessary with 6.0 barrel burr, starting with widening the roof and then the lateral wall at the anterior aspect of the notch. Then, with a gentle painting motion, the anterior roof and anterior lateral wall are smoothed using strokes from posterior to anterior. Roofplasty and notchplasty should be confined to the anterior aspect of the femur to avoid changing the insertion point of the ligament. Just enough bone should be taken from resident's ridge to see the back of the femoral condyle. The curette is used as a final check of notch size, for confirmation of the location of the posterior aspect of the notch, and to create a flat area for the tip of the retrograde guide.

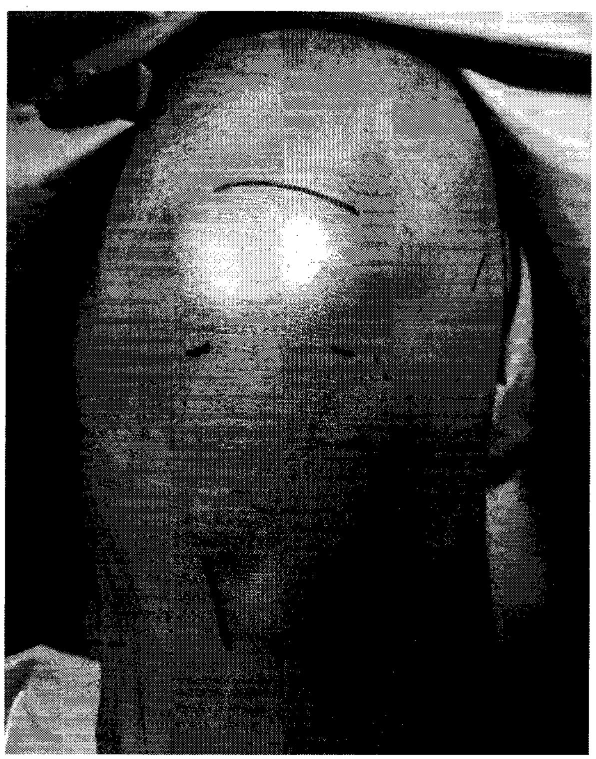

FIGURE 2. Usual skin incisions: superomedial, anteromedial, and anterolateral arthroscopy portals, a transverse incision for quadriceps tendon harvest and 2 incisions for ACL tunnels.

Femoral Tunnel Preparation

A 2- to 3-cm lateral incision through the skin and iliotibial band is made. The distal extent of the incision should be just proximal to a vertical line extending from the fibular head with the knee flexed to 90 degrees. Bluntly dissect and sweep the vastus lateralis anteriorly with a finger, and place a reverse Parker or Z-retractor under the vastus with the knee in extension. An Army-Navy is used to retract inferiorly and distally. Use electrocautery to incise the periosteum longitudinally to the level of the flare of the lateral femoral condyle–shaft junction, coagulating the circumflex vessels. A periosteal elevator is also used to elevate the periosteal flap to the posterolateral border of the femur. Place the rear entry introducer through the anterolateral arthroscopy portal, guiding it over the top to visualize the tip in the lateral wound. Keep the tip against the posterior aspect of the femur. Check the retrograde femoral guide to be sure that it is on the correct side (right or left). Pass the femoral guide into the notch, and raise the introducer to vertical to disengage the guide and remove the introducer. Insert the "bullet" into the guide through the lateral incision. Insert the arthroscope, and orient the camera to vertical by referencing the camera externally and the femoral condyles in the arthroscopic view. The retrograde femoral guide should be held with the thumb on the top of the bullet, leaving room for the assistant to place the guide pin into the hole, and for 2 fingers on the handle (Fig. 3). Orient the guide with a panoramic view to allow placement in the correct clock face position (1 or 11 o'clock). Finally, get

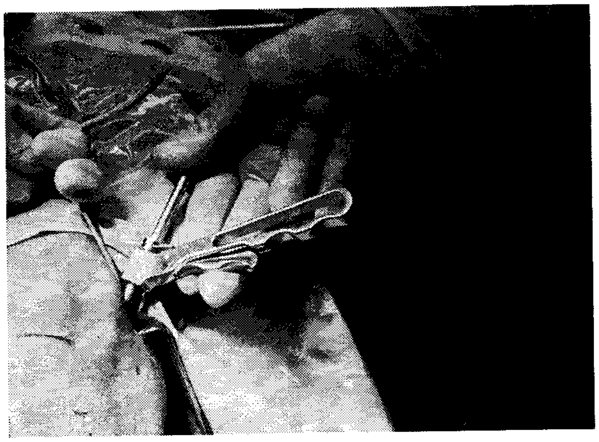

FIGURE 3. Demonstration of thumb and 2-finger control of the retrograde femoral guide.

a closer view of the over-the-top, and place the guide 4 mm anterior to the posterior femoral cortex. The pin comes out 1 mm anterior to the tip of the guide with both Acufex (Smith & Nephew, Andover, MA) and Linvatec (Key Largo, FL) retrograde guides. Rotate the handle of the femoral guide up to secure the tip in the bone. An assistant inserts a 2.4-mm trocar-tipped passing pin using high speed and low pressure on the drill. After pin position is checked arthroscopically, the femoral guide and bullet are removed. Check manually that there is room for the desired size tunnel on the lateral femoral cortex. An old curette is placed over the tip of the guide pin while the tunnel is drilled to protect the PCL. A 10-mm drill or the desired size, is used with the graft sizing tube as a drill sleeve to protect the skin. Some of the posterior cortex should be removed with the drill. Blowing out the entire back wall is of no consequence. A half-round rasp is used to smoothe the anterior superior tunnel edge. Place a plug in the hole through the lateral incision to minimize water leakage.

Tibial Tunnel Preparation

Debride the ACL stump with the shaver down on the tibial eminence to remove the overlying soft tissue. Often a small blood vessel is seen in the middle of the ACL footprint and can be a helpful landmark for pin placement. A 3-cm longitudinal incision is made 1 cm medial to and adjacent to the tibial tubercle. Prepare the tunnel site 1 cm medial to the tibial tubercle with an elevator. Place the tibial guide set on 45 degrees into the appropriate position in the middle of the ACL footprint, which is approximately 7 mm anterior to the PCL and in line with the anterior horn of the lateral meniscus. Pass the guide pin 1 cm into the joint and check its position of entry to ensure proper placement. The pin should be adjacent to the PCL. Move the knee into full extension to ensure that there will be adequate graft clearance within the notch. Drill the tunnel using the graft-sizing tube and skin rake for skin protection. Before entering the knee joint, collect the bone reamings for later placement within the patellar defect. Complete the drilling and remove the debris from the tunnel opening with the large shaver and/or pituitary rongeur. Smoothe the anterior tunnel entrance with a curved tunnel rasp.

Quadriceps Tendon Harvest

A 4- to 5-cm transverse incision at the superior border of the patella is made with the knee flexed 90 degrees. Obtain hemostasis and use electrocautery to dissect through the subcutaneous tissue and superficial fascia in line with the skin incision. A long thin Richardson retractor slid under the proximal fascia exposes the quadriceps tendon. Angle the incision of the superficial fascia slightly proximally and in both the medial and lateral directions if more proximal exposure is necessary. Dissect on the superficial and deep sides of the distal aspect of the superficial fascia overlying the patella, and split the fascia distally. Measure and outline a 10 mm by 25 mm plug with electrocautery over the middle of the proximal patella. An oscillating scoop saw is used to harvest the bone plug while the knee is flexed enough to stabilize the patella in the trochlear groove (Fig. 4). Place the bone plug back in the defect and drill 2 holes in the bone plug with a 2.4-mm trocar-tipped passing wire. A #5 braided polyester suture is passed through each drill hole and tied (the knot is tied more distally for the distal hole suture for proper identification). A fresh #10 blade is used to harvest the central rectangle 1 mm in width and 90–100 mm in length, with care taken to avoid violating the suprapatellar pouch (Figs. 5 and 6). Curved Mayo scissors are used to cut the proximal aspect of the graft.

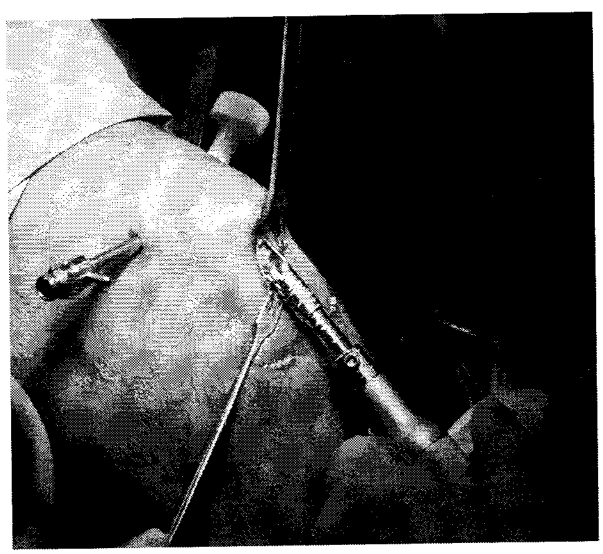

FIGURE 4. Patellar bone plug harvest with scoop saw.

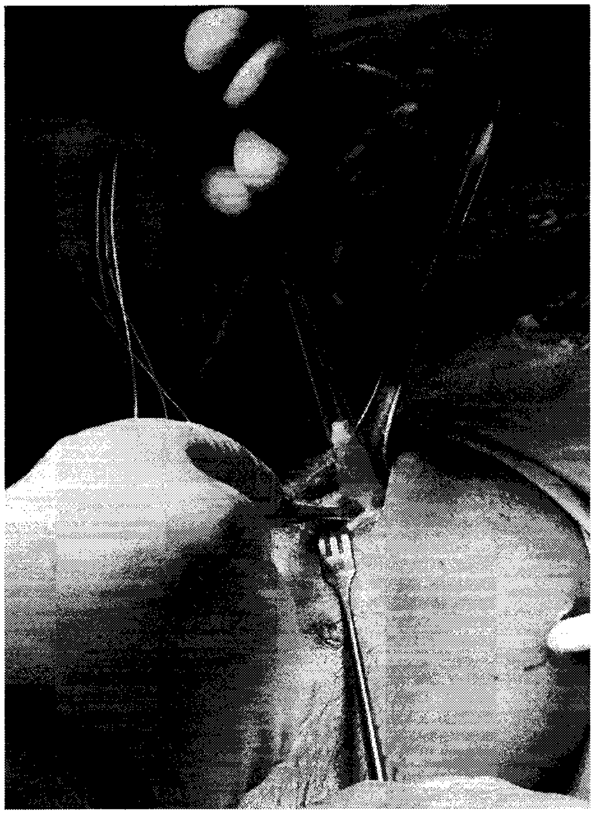

FIGURE 5. Quadriceps tendon harvest.

The graft is taken to the back table, and the tendinous portion split along its natural fat plane to a point 30 mm from the bone plug. A #5 braided polyester whip-stitch is placed up and down one limb of the graft, with the stitch at the apex of the split traversing the entire thickness of the graft. This step is repeated for the other graft limb. The tendon–bone interface is marked with a pen, and the graft is passed through the appropriate sizing tube to ensure easy passage.

FIGURE 6. Measuring the quadriceps graft length before harvest completion.

Graft Passage

A large (9.5-mm) Gore smoother tool (Smith & Nephew, Andover, MA) is selected for 10-mm tunnels, and a small (7.9-mm) smoother is used for 8- or 9-mm tunnels. The smoother is passed blindly through the tibial tunnel through the joint, exiting the lateral wound. Placing a gentle, smooth bend at the end of the smoother will facilitate its passage (Fig. 7). Army-Navy retractors are used to protect the skin as the smoother is slid back and forth while the knee is taken through flexion and extension (Fig. 8). The arthroscope can be used to double check graft position and adequacy of the notchplasty. The sutures of the patellar plug are then passed through the femur as the smoother is removed. The sutures are used to position the plug in the femoral tunnel with the cortical side posterior. Pulling only on the distal suture facilitates the turn of the bone plug into the femoral tunnel.

Graft Fixation

The graft is positioned within the tunnels and visualized to ensure proper orientation. The guide wire is placed along the anterior, cancellous surface of the bone plug to prevent the interference screw from cutting the graft.

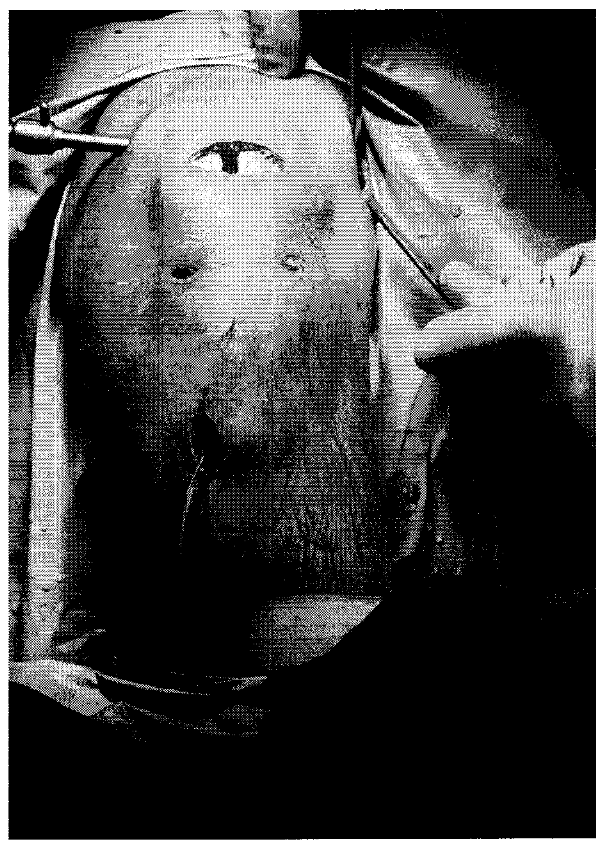

FIGURE 7. Passage of the Gore crucial smoother. Note the bend and orientation of the proximal smoother to facilitate blind passage.

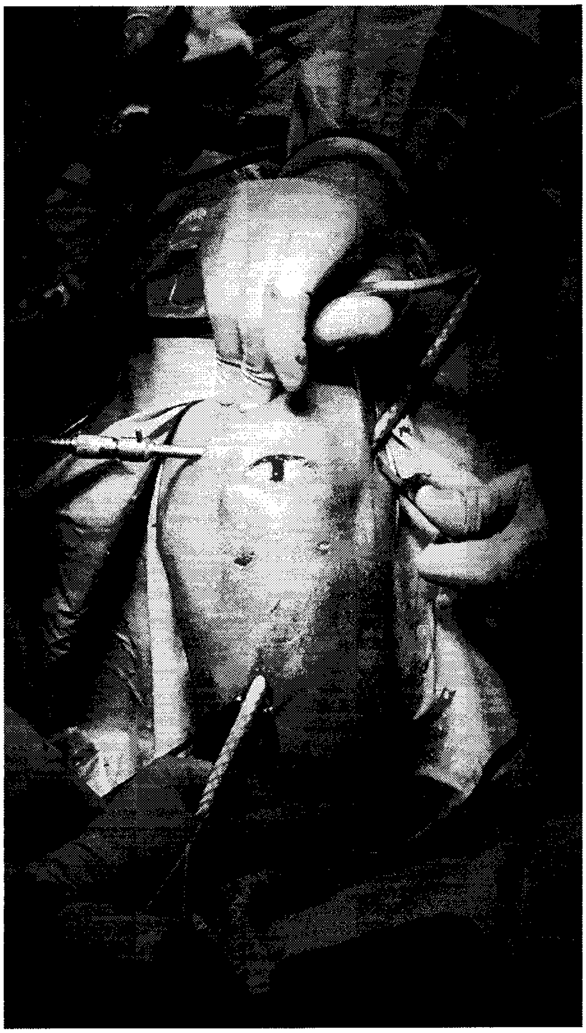

FIGURE 8. Gore crucial smoother in position to complete tunnel preparation and facilitate graft passage.

The desired size absorbable, cannulated interference screw is then inserted down the femoral tunnel, and the wire is removed. A 9 mm × 25 mm screw is most frequently chosen for a 10-mm graft in a 10-mm tunnel. The tibial sided sutures are pulled firmly to ensure good fixation. The knee is taken through a complete range of motion while the surgeon holds onto the quadriceps tendon graft sutures and is cycled 20 times. Isometry can be double checked by keeping the hand holding the sutures firmly against the anterior tibia. The arthroscope is used to fine tune graft placement. The guide wire is then placed to push the graft in the desired direction within the tibial tunnel, which generally places the pin anterior and lateral to the graft. The desired size cannulated, absorbable interference screw is then inserted to a position just distal to the joint, and the guide wire is removed. An 11 mm × 30 mm graft is generally chosen for a 10-mm tunnel. Final graft position is checked with the arthroscope, and the knee is examined for stability with the Lachman test. A tight fit is expected with the oversized interference screw, but if the screw goes in easily, or fixation is not 100% assured, tie the sutures over a plastic button.

Wound Closure

All wounds are irrigated with copious amounts of fluid. Cut the bone plug sutures on one side close to the tunnel to facilitate removal of the entire suture. The iliotibial band is repaired with interrupted figure-8 "0" Vicryl sutures. A "0" Vicryl running suture is placed to close the quadriceps tendon donor site gap. The saved bone graft fragments are placed into the patellar defect, suture is tied in a figure-8 fashion to prevent bone fragments from displacing superiorly. The superficial fascia is reapproximated with "2-0" Vicryl The subcutaneous tissue and skin are closed in layers. The knee wounds are then covered with nonadherent gauze, and the dressing sponges are secured with sterile cast padding and a thigh-high support stocking. A cryo/cuff (Aircast, Summit, NJ) and hinged knee brace locked in extension are placed over the dressings.

■ RESULTS

In 1979, Marshall et al first described the technique of utilizing the middle one-third of the patellar tendon and its extension into the quadriceps tendon as a graft for ACL reconstruction.[21] Marshall's technique was modified by Blauth in 1984.[11] Howe et al presented a retrospective review in 1991, on 89 of 112 patients who underwent an ACL reconstruction using Marshall's technique.[22] Ninety-three percent of the patients had no significant pain, and 95% experienced no giving way symptoms at 10 years postreconstruction. In 1995, Fulkerson and Langeland reported early follow-up on 28 patients who had undergone quadriceps tendon ACL reconstruction.[23] No quadriceps morbidity was reported, and the patients were highly satisfied with rapid rehabilitation and minimal pain. In 1999, Chih-Hwa et al also reported favorable results on 12 patients at 18 months of follow-up.[24] In 1998, Griffith et al reported a prospective study of 56 patients who underwent quadriceps ACL reconstruction and compared them to a matched group of patients who had patellar tendon grafts.[14] Both groups were clinically evaluated at 1 year, and no statistically significant differences were found regarding swelling, crepitus, or with the Lachman, pivot shift, and KT-1000 tests. There were also no statistically significant differences noted with radiographs in these patients. The donor side morbidity was significantly less for patients reconstructed with a quadriceps tendon autograft.

■ COMPLICATIONS

Dropped Graft

The best solution is prevention. After harvest, the graft is placed in a saline-soaked sponge in a basin in the middle of the back table. Because the graft will stick briefly to a glove, no one touches it until it is ready to go into the patient. Although studies have looked into ways of graft decontamination using a variety of antibiotics, soaks, serial dilution, and agitation in vitro, bacteria still remain. Our preference is to change the graft choice to patellar tendon autograft, which can be harvested through the existing transverse incision and a small proximal extension of the tibial tunnel incision.

Drilling Through Guide Pin

Again the best solution is prevention. Because the assistant will generally drill the femoral tunnel, failure of the drill to progress in the tunnel must be recognized as the precursor to drilling through the pin. It is helpful to get the proper angle by placing the drill bit down to bone first and then advancing the tunnel-sizing tube to protect the skin. It is helpful to remind the assistant to break through the lateral cortex with high speed and high pressure on the drill and then let the pressure off so the drill will follow the pin. Early recognition of failure to advance the drill enables easy replacement of the weakened guide pin. If the pin does break, it can be retrieved. The pin within the joint can be pushed back with the curette, and the pin retrieved with a pituitary rongeur down the femoral tunnel.

Notch Visualization

"Red-out" or poor visualization because of bleeding is best avoided by prevention. The use of a tourniquet, large inflow cannula, and arthroscopic pump controls most routine bleeding during notch preparation. Because the vessels run posterior to the joint capsule behind the posterior horn of the lateral meniscus, they can be damaged by the use of sharp or motorized instruments and electrocautery in the posterior compartment. A curette is the safest instrument for soft tissue and bony work in this area. Keeping the rear entry introducer tip against the posterior femoral cortex during delivery of the tip into the lateral incision also minimizes injury risk. Managing "red-out" includes troubleshooting the fluid, pump, and inflow situation. Consider a temporary increase in pump pressure, adding 1 ampule of epinephrine into the arthroscopy bag, using suction in the joint to increase flow, and cauterizing of any small visible bleeders. Attention to pulses and perfusion postoperatively allows for early detection and repair of significant vascular injuries.

Infection

Postoperative pyarthrosis usually manifests itself in the third postoperative week. Early signs and symptoms include increased pain, swelling, and regression in rehabilitation. Have a high index of suspicion and err on the side of aspiration in questionable cases. Prompt arthroscopic lavage with arthroscopic synovectomy and drain placement should be combined with broad-spectrum intravenous antibiotics after cultures are taken. The limb is splinted in extension with a bulky pressure dressing for 2 days, at which time a second-look arthroscopy with lavage is performed to remove blood clots. In acute infections, the graft can sometimes be salvaged. Patients are followed with serial laboratory and clinical exams, 6 weeks of appropriate intravenous antibiotics, and resumption of rehabilitation when the infection is under control.

■ POSTOPERATIVE MANAGEMENT

Preoperative patient teaching is reinforced postoperatively with emphasis on the importance of achieving complete extension, quadriceps control, and decreased swelling. Patients are empowered to complete much of the rehabilitation at home under the guidance of a therapist using a protocol outlined by Fischer and colleagues.[25]

TABLE 1. *Four phases of rehabilitation*

Phase	*Emphasis*	*Post-op*	*Goals*
1	Range of motion	1–3 weeks	Gain and maintain full extension Decrease postoperative swelling Progress towards independent walking Initiate strengthening program
2	Strength	4–6 weeks	Increase knee ROM: 0–135 degrees Confident, smooth gait pattern Begin functional strengthening
3	Power	7–12 weeks	Attain full ROM Advance functional strengthening Walk up and down stairs using both legs equally Run
4	Function	13–24 weeks	Advance agility and power training Achieve normal activities on irregular surfaces

The program is divided into 4 phases: range of motion, basic functional strengthening, advanced functional strengthening, and improvement in speed and agility with the goal of return to sports at 6 months (Table 1). Braces are used only as needed, to facilitate confident reentry into desired sports.

■ POSSIBLE CONCERNS AND FUTURE OF THE TECHNIQUE

The 2-incision technique for ACL reconstruction has been, and will remain, an important tool in the knee surgeon's arsenal because of its accuracy and versatility. Long-term data on the outcome of quadriceps tendon grafts is lacking, but preliminary evidence is very positive. Central quadriceps tendon grafts are likely to increase in popularity in the future. This technique is a particularly good adjunct for revision surgeries.

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