Techniques in Orthopaedics®
20(4):361–371 © 2005 Lippincott Williams & Wilkins, Inc., Philadelphia

Anterior Cruciate Ligament Reconstruction Using an Endoscopic Technique With Patellar Tendon Autograft

Kyle R. Flik, M.D.* and Bernard R. Bach, Jr., M.D.†

Summary: The single-incision endoscopic-guided ACL reconstruction using patellar tendon autograft is advocated for its high ultimate strength, bone to bone healing, and interference fixation. Optimal outcomes are obtained when attention is paid to crucial technical aspects of the procedure. In addition, attempts should be made to reestablish full range of motion in the affected knee prior to surgery. The technically-demanding graft harvest portion of the procedure focuses on obtaining a graft with appropriately-sized bone plugs and adequate tendon girth while minimizing trauma to the knee. Notch preparation and tunnel placement allow for the graft to be appropriately oriented without impinging in the notch in extension. Metal interference screws are used for fixation both at the femur and the tibia. An aggressive physical therapy program is initiated postoperatively. **Key Words:** Patellar tendon—Single-incision—Endoscopic—Technique.

Anterior cruciate ligament (ACL) reconstruction is one of the most common surgical procedures performed by orthopaedic surgeons. The number of ACL tears continues to rise because of the growing population and the increased involvement in sport at many levels, especially among young women and the middle-aged. There are over 100,000 ACL reconstructions performed annually in the United States using a variety of techniques according to the American Academy of Orthopaedic Surgery.

Most orthopaedists agree that a patient with an ACL tear who wishes to return to activities that involve cutting or pivoting would benefit from reconstruction. However, there is controversy as to the best type of graft, fixation, and surgical technique that should be used. Regardless of the technique used, the primary goal of ACL reconstruction surgery is to provide a pain-free knee that will be functionally stable. The bone-patellar tendon-bone (BPTB) autograft is the most widely chosen graft source and has the longest and most reviewed track-record.[1–4,6,7,9,11,18,26,29,31,33,36] Advocates emphasize its high ultimate strength, bone to bone healing, and interference fixation. This article describes our endoscopic single incision technique using a central third ipsilateral BPTB autograft. Surgical pearls and potential pitfalls are discussed.

From the *Department of Orthopedic Surgery, Division of Sports Medicine, Rush University Medical Center, Chicago, Illinois; †Division of Sports Medicine, Northeast Orthopaedics, LLP, Sports Medicine, Executive Woods, Albany, New York.

Address correspondence and reprint requests to Bernard R. Bach, Jr., MD, 1725 W. Harrison St., Suite 1063, Chicago, IL 60612. E-mail: brbachmd@comcast.net

SURGICAL TIMING

When assessing a patient with an ACL deficient knee, contraindications to surgical fixation using BPTB autograft must be considered. Inappropriate candidates include those with severe degenerative changes in the knee, patients unable or unwilling to comply with rigorous postoperative rehabilitation, skeletally immature patients, and people with inadequate or poor quality patella tendon. Those that may not tolerate kneeling discomfort or numbness on the anterior knee should be considered for an alternate graft choice.

Surgical timing is controversial, but much of the literature will support delaying surgical reconstruction until the patient has achieved near full range of motion, strength, and control of the knee with little or no effusion.[23,30,34] The risk of arthrofibrosis is higher in those patients who undergo early reconstruction while the knee

is still acutely inflamed. If a locked or displaced meniscus tear or a loose body is present, early surgical management is warranted.

PATIENT PREPARATION

The process of patient preparation begins at the first encounter by providing a thorough explanation of the procedure and the rehabilitation process. It is crucial that the patient has appropriate expectations regarding the timing and potential for full return to activity. On the day of surgery, review of the consent should be routine. The size and suitability of the patella and patella tendon should be assessed. The possibility of requiring an alternate graft source should be discussed with the patient.

Once in the operating room, a prophylactic dose of preoperative antibiotics is routinely administered. After anesthesia has been administered, a thorough examination of both knees in the supine position is performed to confirm instability. A positive pivot shift examination is pathognomonic of ACL insufficiency. The Lachman test, anterior and posterior drawer, varus/valgus stress, and posterolateral instability at 30 degrees and 90 degrees should be assessed. Failure to recognize concomitant ligamentous pathology is a preventable cause of ACL reconstruction failure.[8,10]

If pivot shift testing is unequivocal for ACL deficiency, then the graft harvest portion of the operation can be performed before diagnostic arthroscopy. This allows for the inferomedial and inferolateral portals to be placed within the operative wound and not through new skin incisions. Additionally, anesthesia time can be preserved by having the graft prepared by an assistant during the initial arthroscopy.

The knee should be cleanly shaven. Place a tourniquet as high as possible on the upper thigh before placing the leg in a leg holder. Secure the contralateral leg in a foot holder with the hip and knee slightly flexed and the common peroneal nerve well padded. Confirm that the operating table is flexed slightly at the waist to remove excessive lumbar lordosis, and that the foot of the table is completely flexed. The knee should be capable of being hyperflexed to cycle the graft once it is passed and during the placement of a parallel interference screw into the femoral tunnel (Fig. 1A,B).

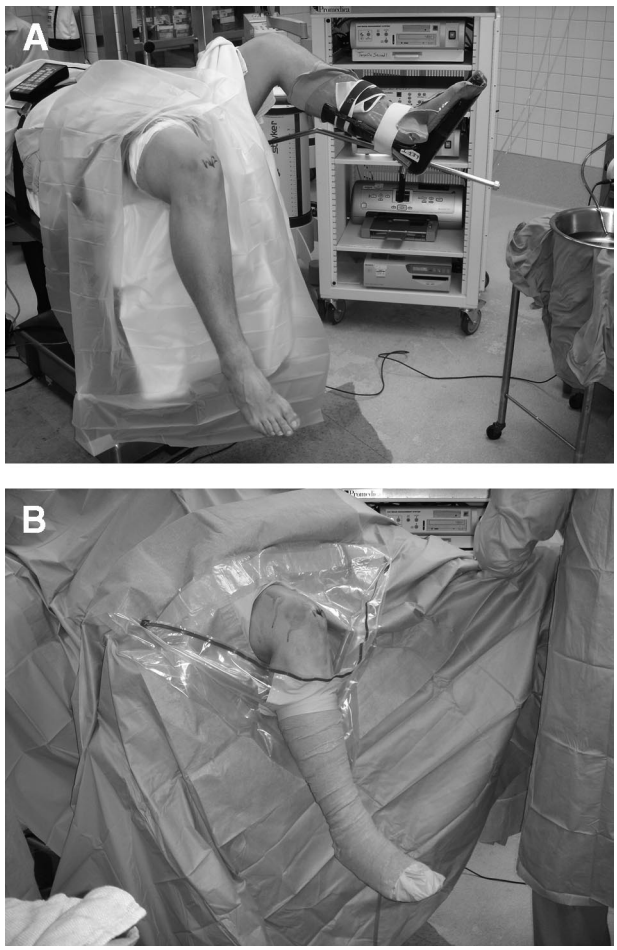

FIG. 1. Photographs of basic OR set-up with patient positioning before (**A**) and after (**B**) draping.

DIAGNOSTIC ARTHROSCOPY

Keep the tourniquet deflated if possible. Establish an outflow portal either superomedially or superolaterally and an inferolateral viewing portal adjacent to but not in violation of the patella tendon. This facilitates visualization around the lateral femoral condyle. Create an inferomedial working portal. Attach the inflow to the viewing cannula. Perform a complete diagnostic arthroscopy to evaluate for articular cartilage damage, meniscus tears, loose bodies, and ACL and PCL integrity. A thorough evaluation includes visualization of the suprapatellar pouch, patellofemoral joint, gutters, medial and lateral compartments, and the intercondylar notch. Additionally, the posterior compartment can be visualized to further confirm the lack of loose bodies or meniscal root tears.

Any repairable meniscus tear is aggressively fixed, as the healing rate is improved when this is performed simultaneously with ACL reconstruction.[19] An inside-out technique allows for vertical mattress suture placement (strongest suture orientation) whereas protecting the neurovascular structures.

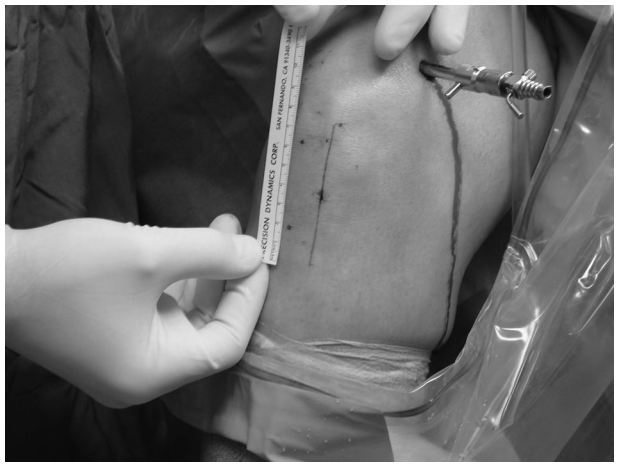

FIG. 2. Photograph of the incision for patellar tendon harvest. Highly mobile skin may allow a slightly shorter incision.

FIG. 3. Photograph depicting the technique for making bone cuts with oscillating saw. For cuts on the right side of the tendon, the saw is held in the right hand with the left index finger in the "axilla" created by the scalpel cut. The thumb of the left hand helps guide the saw blade.

BPTB GRAFT HARVEST

With the knee flexed, a vertical incision from the distal pole of the patella extending distally to the inferior portion of the tibial tubercle is sufficient to gain access to the patella and the tubercle for making the bone cuts. Check skin mobility as a smaller incision is frequently possible (Fig. 2). Keeping the incision just medial of the midline will enable the surgeon to make the tibial tunnel through the same incision. Incise sharply down to the transverse fibers of the paratenon and create skin flaps. Using a number 15 blade, incise the paratenon in the midportion of the patella tendon and extend proximally and distally with Metzenbaum scissors. Undermine beneath the paratenon edges medially and laterally to expose the entire width of the patella tendon.

Measure the width of the tendon and mark the midline proximally and distally with a marking pen. Plan to harvest a 10-mm-wide graft from the middle third of the tendon with 10 × 25-mm bone plugs, which will be appropriate for most knees. Keeping the knee flexed to put the tendon on stretch, use a number 10 scalpel blade to incise the tendon on one side of the graft. Allow the scalpel to follow the natural longitudinal fibers of the patellar tendon (PT). Extending the knee will make it easier to incise the patellar and tibial bone block edges. Use a retractor distally to protect the skin while making the longitudinal cuts with the scalpel. Cut the other side of the graft to yield a 10 mm-wide graft. Pay close attention to remain parallel to the first cut. Outline both the distal cross cut on the tibial tubercle and the proximal cross cut on the patella.

Using a number 238 blade on an oscillating saw, create the tibial and patella bone plugs. The tibial bone plug is obtained first. While using the saw, the nondominant hand of the operating surgeon should be in contact with the patient's leg at all times. Use the dominant hand on the saw. The non-dominant thumb should stabilize the saw while the index finger protects the graft by opening the axilla between the graft and the adjacent PT (Fig. 3). Score the tibial cortex and remove an equilateral triangle of bone with the saw. This maximizes the remaining bone in the tubercle region beneath the remaining two-thirds of the tendon. When making the distal cross cut, hold the saw at a 45 degree oblique angle to the cortex and use the corner of the blade to prevent extension of the cut beyond the longitudinal cuts.

Leave the tibial bone block temporarily in place and turn attention to the patella bone plug. This cut is created as a trapezoidal shape that may help avoid penetration into the articular surface. The depth of the cut should be no more than 6 or 7 mm. Again, make the proximal cross cut with the saw held at a 45 degree angle. To safely complete the corner cuts, place the blade parallel into the longitudinal medial and lateral bone cuts and cut from distal to proximal.

Use a half-inch or quarter-inch curved osteotome to gently raise the tibial bone plug from its bed. Avoid overaggressive use of the osteotome or levering with the osteotome that may cause splintering of the bone plug or patella fracture. Holding the tibial bone plug with a lap pad, gently remove the patellar plug. Fat pad or other soft tissue attachments should be removed with a Metzenbaum scissors. The graft is then taken by the surgeon and placed on the back table for preparation. It is important to

communicate graft location and responsibility for graft safekeeping with all members of the operating team. Pearls and pitfalls of graft harvesting is the topic of an entire subsequent chapter. Please review this chapter for further details and recommendations regarding BPTB graft harvest technique.

GRAFT PREPARATION

Measure and record the total graft length, the length of the bone plugs, and the length of the tendinous portion. Usually the tibial plug is used in the femur and the patellar plug is used in the tibia. However, using the longer plug on the femoral side will decrease mismatch between tibial tunnel and graft. Use a small rongeur to contour the bone plugs that should be sized to fit through tunnels 9 to 11 mm in diameter. In the majority of cases we size our bone plugs for 10 mm. We usually drill a 10 mm diameter femoral tunnel and an 11 mm tibial tunnel to allow easy graft passage and to minimize soft tissue delamination. Save excess bone for grafting the bone plug donor sites. If one plug is slightly wider than the other, it should be used on the tibial side. The femoral plug should be contoured with a slight bullet shape to allow smooth passage through the tunnels.

Use a 0.062-inch K-wire or similarly sized drill bit to make two drill holes approximately 5 mm apart in the shorter (tibial) bone plug. These are made parallel to the cortical surface and through the cancellous portion of the bone. Place a no. 5 Ticron suture (Davis & Beck, Wayne, NJ) in each hole. The interference screw will be placed along the cortical surface, so avoid placing sutures there. We use a "push-up" technique for placing the femoral bone plug, so we do not place sutures in the femoral bone plug. If a "pull-through" technique is used, then drill holes and sutures would be placed in a similar fashion in the femoral bone plug.

Use a sterile marking pen to mark the junction between the femoral bone plug and the tendon that will make intra-articular visualization easier. The cortical surface of the tibial bone plug is also marked to help with graft rotation orientation (Fig. 4). Place the prepared graft wrapped in a moist lap sponge into a kidney basin and put it in a safe location on the main instrument table. The location of the graft is announced to the team.

NOTCH PREPARATION

The work needed to prepare the intercondylar notch region before drilling tunnels can be performed while the graft is being prepared on the back table. A 5.5 mm full-radius shaver is used to remove fat pad and ligamentum mucosum if visualization is poor, and to remove remaining ACL tissue from the lateral wall of the notch and tibial footprint. On the tibial side, the ACL stump should be sufficiently removed to avoid development of a Cyclops lesion.[12,13,17,22] Residual ACL tissue removal may be expedited with the use of arthroscopic scissors, an osteotome, or arthroscopic electrocautery along with the shaver. The amount of bone that is removed from the notch is variable. It is essential only to remove enough bone to prevent graft impingement, especially in full knee extension, and to allow visualization of the posterior over-the-top position. We have evolved to initiating our notchplasty with a one-quarter inch curved osteotome placed through the inferomedial portal to facilitate the notchplasty (Fig. 5). Bone fragments are re-

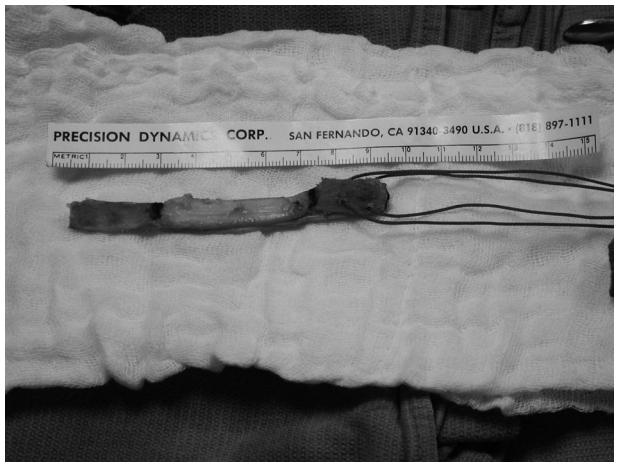

FIG. 4. Photograph of prepared ACL patellar tendon graft.

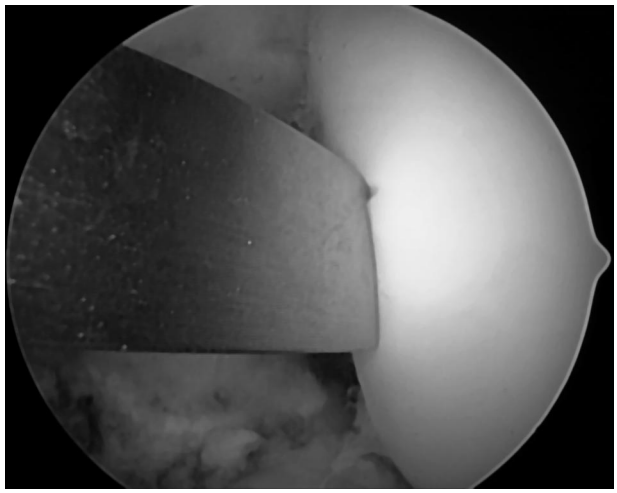

FIG. 5. Arthroscopic photograph showing the initiation of notchplasty with use of curved osteotome.

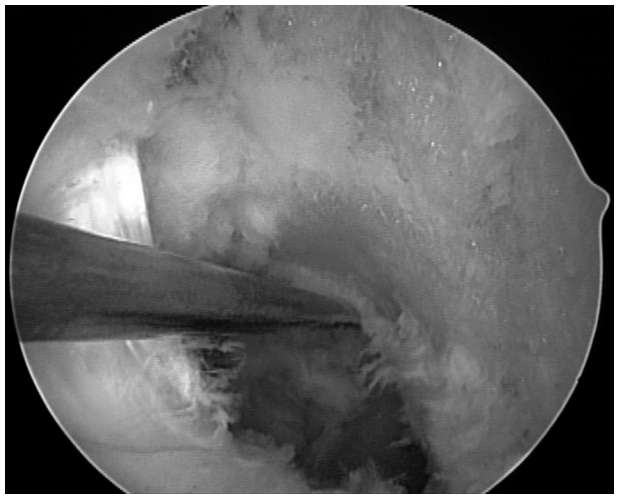

FIG. 6. Arthroscopic photograph showing the probe confirming the over-the-top position.

moved with a grasper and used for grafting the distal patella and tibial tubercle defects. Notchplasty is completed with a spherical 5.5 mm bur. A spherical bur is preferred to a barrel bur as it is less likely to create troughs in the lateral intercondylar wall. We often use the bur on "reverse" particularly with left knees to reduce the torque effect and tendency of the bur to "dig" into the lateral wall of the notch.

There is a vertical ridge along the lateral wall of the notch approximately two-thirds of the distance posteriorly that can be mistaken for the true posterior outlet of the notch ("resident's ridge"). Always take a probe to feel for the true back over-the-top position. This should feel like a sharp edge; if it feels rounded, one should continue to fine tune this posterior region (Fig. 6). Be cognizant, however, not to remove an excessive amount of bone at the ACL femoral insertion since this will cause lateralization of the isometric point.

TIBIAL TUNNEL

A tibial tunnel guide is used for drilling the tibial tunnel. In an attempt to match tunnel and graft length and to avoid mismatch, the $n + 07$ rule is helpful.[24,28] This rule, which is useful but not absolute, adds 7 to the tendinous graft length to suggest a setting for the tibial guide in degrees (eg, 48 mm $+7 = 55$ degrees) that will provide a close match between graft and tunnel lengths. We usually drill at a 55 degree angle, occasionally increase this to 60 degrees with longer tendons, but rarely will drill below 50 degrees with shorter tendons. The guide is placed through the inferomedial portal with the aiming stylet positioned where the tibial tunnel will enter the joint. We frequently will create an accessory inferomedial portal or transpatellar portal to further distalize the initial starting point for the tibial drill tunnel. This creates a longer tibial tunnel. Accurate guide placement is best performed by using three distinct landmarks:[15,16,25] 1) the posterior aspect of the ACL tibial footprint; 2) a line drawn along the posterior edge of the anterior horn of the lateral meniscus toward the midpoint in the notch just lateral to the medial tibial spine; and 3) seven millimeters anterior to the PCL. We recommend entering the posterior aspect of the visible tibial footprint since the point that the guide-pin is seen entering the joint is posterior to where it actually exits the plateau surface because of the soft tissue overlying the plateau. It is also important to note that as the reamer will enter the joint in an oblique orientation, the more horizontal the tunnel is, the larger the intra-articular ellipse is created.

The tibial tunnel guide systems are variable with respect to where the guide-pin makes contact with the intra-articular stylet portion of the guide. It is important to be familiar with your specific guide. For example, with the Acufex Protac (Smith and Nephew Endoscopy, Mansfield, MA) the guidepin contacts the elbow of the aimer above the plateau surface. Therefore, we place the aimer stylet more posteriorly with respect to the anatomic reference marks outlined above.

Once the stylet is properly placed intra-articularly, the sleeve of the guide is advanced onto the anteromedial tibial surface to indicate where the tibial tunnel starting point will be. The tibial tunnel entrance is usually 1.5 cm medial to the tubercle and 1 cm proximal to the pes anserine tendons. Once this location is identified, a medially based rectangular periosteal flap is made to expose cortical bone. The tibial tunnel position is important in that it will dictate to an extent the position of the femoral tunnel, which is created through this tibial tunnel. While creating the periosteal flap, take care not to damage the nearby superficial medial collateral ligament and the pes anserine tendons.

Slide the cannulated guide arm up to the tibial cortex through the periosteal window. In general this position on the tibial cortex will be midway between the tibial tubercle and the posteromedial flare of the tibia and will create a 30 degree angle with the longitudinal axis of the tibia. This will create an appropriate medial to lateral oblique orientation that allows a transtibial approach to the anatomic femoral ACL insertion. Drill the guide pin through the guide while observing arthroscopically as it enters the joint (Fig. 7). Remove the guide and check that the guide pin position is appropriate and that there is adequate clearance in the superior notch when the leg is brought into extension. The pin can be advanced with a

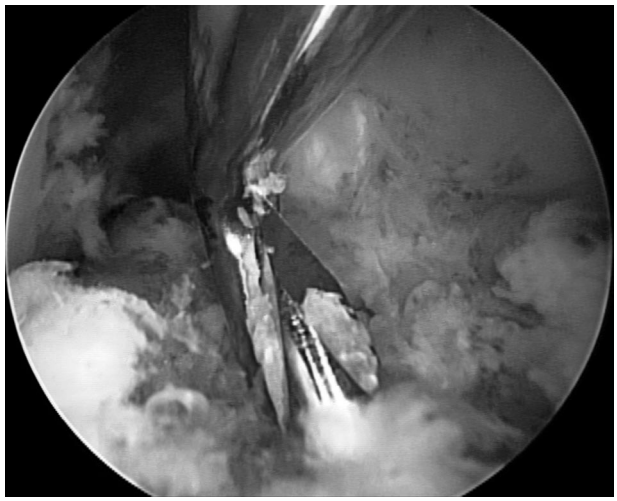

FIG. 7. Arthroscopic photograph depicting the tibial guide pin entering joint.

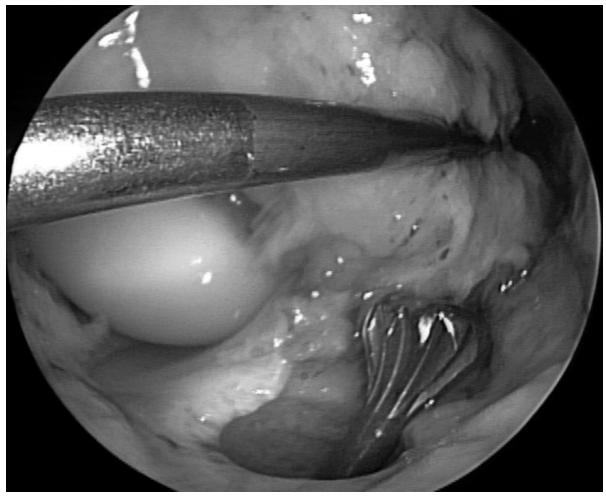

FIG. 8. Arthroscopic image showing the campfer reamer removing bone on the posterior aspect of the tibial tunnel.

mallet until it engages the femoral intercondylar roof. This helps stabilize the pin during reaming and reduces the posterior ledge of bone created when the reamer translates anteriorly as it obliquely enters the joint.

Ream over the guide pin with the appropriately sized cannulated headed reamer. We collect the bone reamings with the help of a cannulated bone chip collector (Linvatec, Largo, FL) for later grafting of our patellar and tibial defects. Turn off the arthroscopy pump before entering the joint with the reamer. Once the tibial tunnel is completely reamed, occlude the tunnel and turn the inflow pump back on. Use the shaver to remove loose bone or cartilage fragments. Place the champfer reamer up the tibial tunnel and ream the back portion of the tunnel and repeat this step using the curved hand rasp to smoothen any posterior ridges at the tunnel's intra-articular aperture (Figs. 8 and 9). This is performed at this juncture because it helps prevent the femoral guide pin from being deflected anteriorly. It also creates a smooth posterior surface against which the new graft will lie.

FEMORAL TUNNEL

The femoral tunnel is usually created using a retrograde trans-tibial-tunnel approach. Place a femoral tunnel offset guide through the tibial tunnel, across the joint toward the posterior aspect of the notch and hook it at the over-the-top position. The 1 o'clock position for left knees and the 11 o'clock position for right knees is ideal. The offset guide is used to minimize the chance of posterior cortical blowout when drilling the femoral tunnel. If a 10 mm bone tunnel is being drilled, then a 7 mm offset guide is used as this will leave a 2 mm posterior cortical bone shell. Always check the femoral offset aimer for accuracy with a Steinmann pin before use, as these devices may be bent or deformed with frequent use that will cause unintended errors in femoral tunnel placement.[5] If the tibial tunnel does not allow for the femoral tunnel to be placed ideally, then create an accessory inferomedial portal, use the femoral guide through the portal, hyperflex the knee to 130 degrees, and drill the femoral tunnel as advocated by O'Donnell.[27]

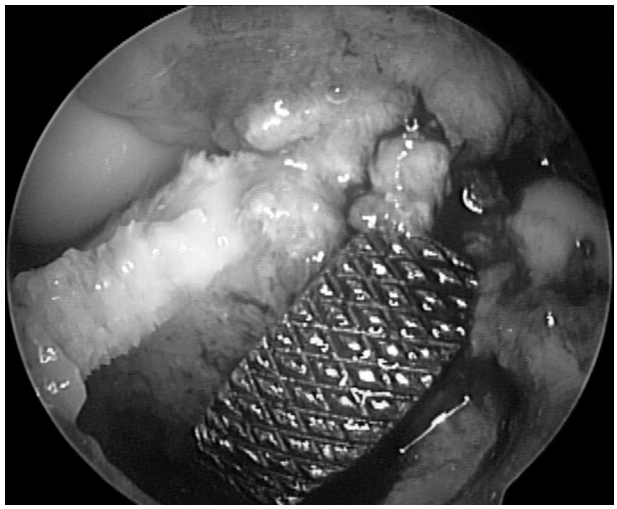

FIG. 9. Arthroscopic image of the hand rasp used to smooth the posterior mouth of the tibial tunnel.

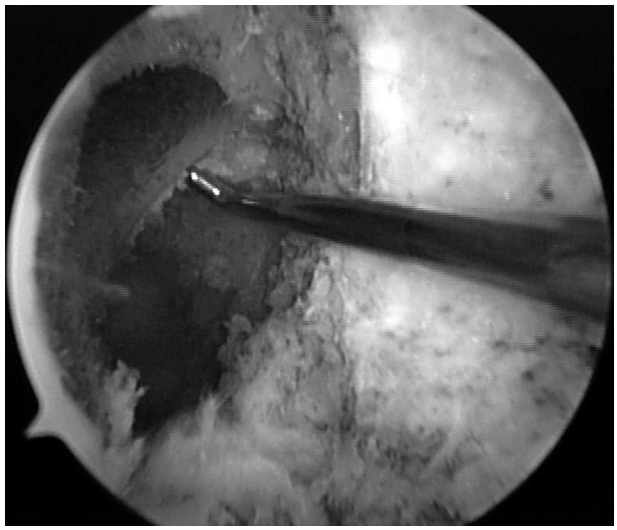

FIG. 10. Arthroscopic photograph taken to confirm the presence of a cortical back wall before completing the femoral tunnel.

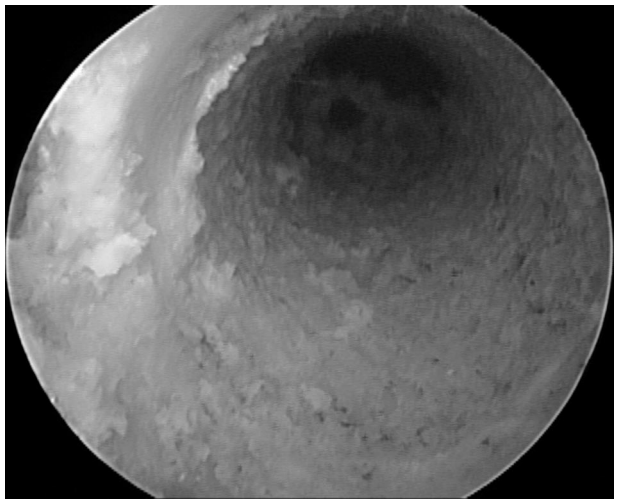

FIG. 11. Arthroscopic image showing the entire femoral tunnel to confirm its integrity.

Before drilling the tunnel, place a probe through the inferomedial portal to protect the PCL. Turn the arthroscopy pump off. A passing Beath pin is not needed in the push-in technique. The guide pin is drilled through the guide approximately 3 cm into the femur. Begin reaming over the guide to a depth of 10 mm. Usually, there is a pitch difference in the sound of the drill, and a "give" sensation as the acorn reamer enters cancellous bone. Back the reamer out and visualize the posterior wall through the tunnel footprint (Fig. 10). Probe to assure cortical integrity. Finally, resume reaming to a depth 5 to 7 mm longer than the length of the femoral bone plug. This allows for the plug to be recessed if there is a graft-tunnel mismatch.

Irrigate the knee at this point with the aid of a shaver to remove loose bone debris. Reaffirm femoral tunnel integrity by placing the arthroscope retrograde up the tibial tunnel and looking directly into the femoral tunnel (Fig. 11).

GRAFT PASSAGE

Obtain the graft from the back table. Using a 2-pronged pusher at the base of the femoral bone plug, advance the graft through the tibial tunnel. Use a curved hemostat through the inferomedial portal with its tips pointed up to grasp the bone plug at the junction of the proximal and middle thirds. Guide the plug using the hemostat into the femoral tunnel with the cortical surface facing posterior (Fig. 12). This allows for the graft to be pushed posteriorly when the interference screw is placed anteriorly along the cancellous surface. Retract the soft tissues around the tibial tunnel so that the tibial bone plug seats easily.

An alternative technique for passage of the graft into the femoral tunnel involves passing a Beath pin (or other passing pin with an open slot at the base for placing suture) up the tibial tunnel, through the knee, through the femoral tunnel and femur, and out the skin of the anterolateral thigh. When using this method, the graft must be prepared with drill holes and passing sutures in the femoral bone plug in addition to the tibial bone plug. The femoral sided sutures are then passed through the eye of the Beath pin and the Beath pin is pulled through the

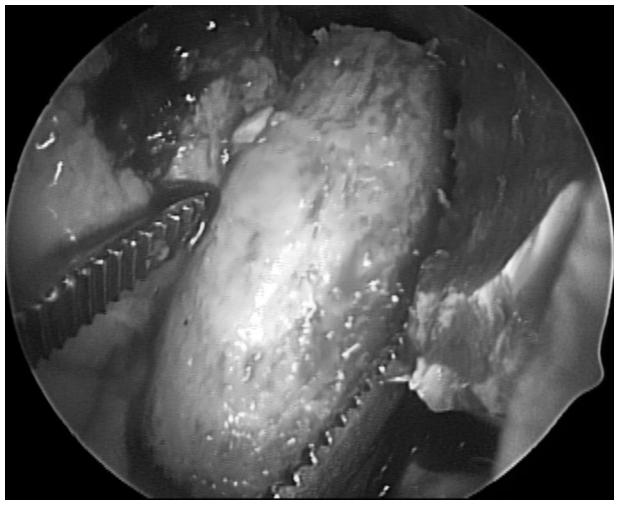

FIG. 12. Arthroscopic image showing the graft being passed into the knee and grasped with a curved hemostat that is used to push the bone plug into the femoral tunnel.

knee and out the anterolateral thigh. The passing sutures on the femoral bone plug and the ones on the tibial bone plug are then held taught as the graft is brought into the knee. Use a probe to assist in the proper orientation of the femoral bone plug in the femoral tunnel. This technique necessitates that the tourniquet is placed more proximally on the thigh, and the knee is hyperflexed during passage of the Beath pin to prevent possible proximal migration and contamination with the tourniquet.

GRAFT FIXATION

The fixation of the femoral bone plug is performed with a 7-mm × 25-mm titanium, cannulated interference screw. A few important steps are taken to facilitate the placement of this important screw as parallel to the bone plug as possible to maximize pull out strength. Screw divergence of more than 15 degrees should be avoided.[14,21,32] With the femoral bone plug seated roughly 85%, place a Nitenol hyperflex guide pin (Linvatec, Largo, FL) into the femoral socket at the 11 o'clock position of the graft against the cancellous surface of the plug. A separate more central inferomedial portal often is needed to help place this guide pin parallel with the graft. Once the guide pin is seated, flex the knee 110 to 120 degrees. The Nitenol pin should slide smoothly into the tunnel. Use a satellite pusher to seat the bone plug flush with the articular surface. Check for graft tunnel mismatch at the tibia. If a significant portion of the tibia bone plug is protruding from the tibial cortex, use the pusher to recess the femoral plug. Other alternatives of managing graft construct mismatch are discussed by Verma in this monograph.

Once the femoral plug is appropriately seated and the Nitenol pin is in proper position, advance a 7 × 25-mm interference screw over the guide wire while maintaining hyperflexion of the knee. Remove the guide pin once the screw is engaged 50% to 66% of its length, otherwise it may be difficult to remove the guide wire once the interference screw is fully seated. Continue to advance the screw until its base is flush with the base of the femoral plug. Be careful not to lacerate the soft tissue of the graft while placing the screw. A graft protection sleeve may be used, particularly if the graft is recessed because of tunnel-construct mismatch (Fig. 13).

While holding the tibial plug sutures, hyperflex and extend the knee fully several times to cycle the graft. Visualize the graft during this motion to assure there is no contact between the graft and the roof of the notch or the lateral wall.

Attention is directed to the tibial bone plug fixation. The graft is rotated 180 degrees externally (toward the lateral side) before fixation. This maneuver orients the cortical surface anterior that pushes the bone plug posterior when the interference screw is placed on the anterior surface of the bone plug. This has the benefit of allowing the cancellous surface of the plug to heal to a cancellous surface. Note that a posterior placed screw would abrade the graft if it extended beyond the bone block. Placement of the tibial screw anterior to the plug is preferred because this avoids potential abrasion of the graft by the screw when the knee is flexed, minimizes the chance of screw divergence, and protects against anteriorizing the graft that may lead to impingement. Rotation of the graft up to 540 degrees does not weaken the construct and can shorten the graft if the tibial bone plug remains proud.[20,35]

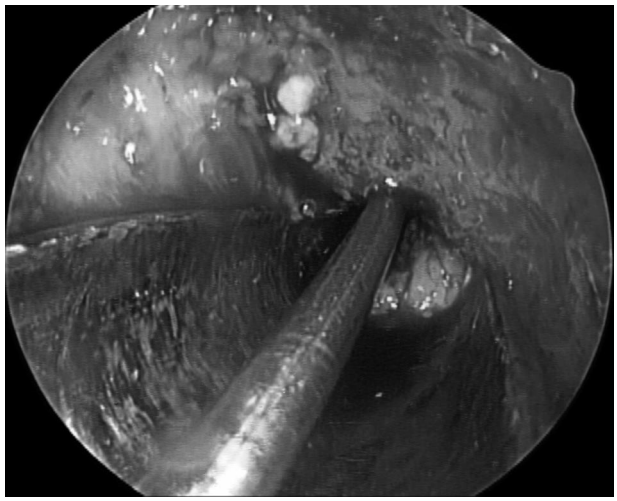

FIG. 13. Arthroscopic photograph of the graft protector sleeve that is used to protect the graft while placing the interference screw.

Position the knee in full extension and pull firmly on the sutures. Place the Nitenol pin anterior to the plug and use a 9 × 20-mm titanium cannulated screw. The screw should be seated just below the cortical surface to minimize the possibility of painful hardware. A longer screw should be used if the tibial plug has been recessed intraosseously, otherwise future removal, if needed, will be difficult.

Visualize the graft a final time with the arthroscope to ensure proper orientation and tension. A gentle Lachman and pivot shift examination are performed. Figure 14 shows an artist's depiction of many of the crucial steps in the procedure.

WOUND CLOSURE

Irrigate the wound with sterile saline. Close the PT defect with no.1 Vicryl sutures (Ethicon, Inc, Somerville,

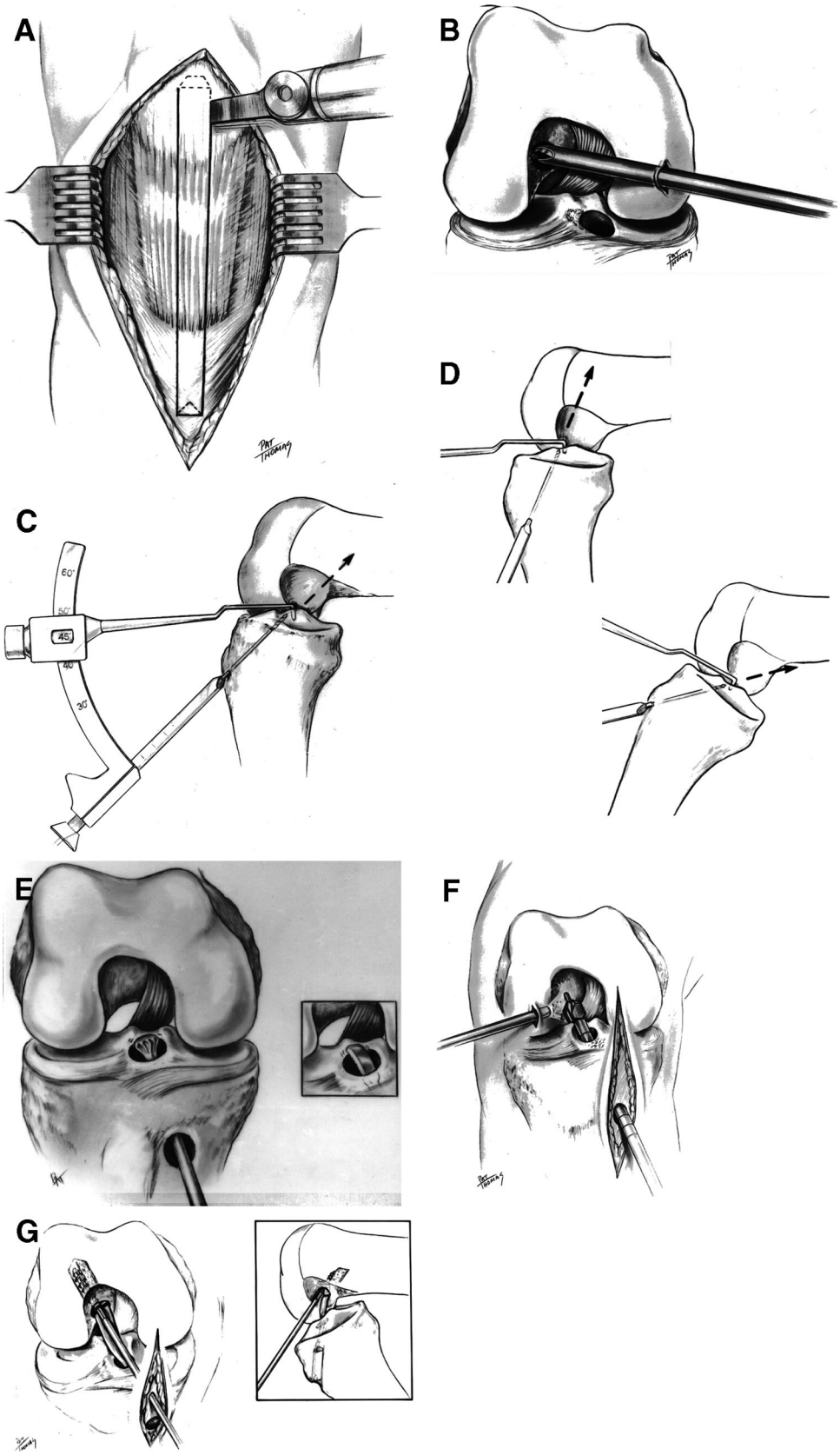

FIG. 14. An artists depiction of many of the crucial steps in performing a single incision BPTB ACL reconstruction. The knee is in flexion with adequate exposure of the entire patellar tendon during the graft harvest (**A**). A large shaver or burr is used to complete the notchplasty of the lateral femoral intercondylar notch. (**B**) The tibial guide is placed with the knee in 90 degrees of flexion. (**C**) Position of the guide pin and knee are important since excessive knee extension will cause the guide pin to violate the posterior cortex of the femur. (**D**) After the tibial tunnel is drilled, a champfer reamer is used to take bone from the posterior mouth of the tunnel. This prevents the femoral guide pin from being diverted anteriorly. (**E**) The femoral tunnel is drilled in 2 steps. The reamer should be advanced approximately 10 mm and removed so that the back wall can be visualized and confirmed. The tunnel is then completed to the appropriate depth. (**F**) After passing the graft, the femoral plug is secured with an interference screw that should be placed over a guide wire as parallel to the bone plug as possible for best fixation. (**G**) (Reprinted, with permission, from: Hardin GT, Bach BR, Bush-Joseph CA et al. Endoscopic single incision ACL reconstruction using patellar tendon autograft: surgical technique. *Am J Knee Surg* 1992;5:144–155.).

NJ) with the knee flexed to prevent shortening the tendon. Close the periosteal window at the tibial tunnel with no. 1 Vicryl. Use any collected bone reamings to pack the patellar bone defect. Close the paratenon with a running 2-0 Vicryl suture, the subcutaneous layer with interrupted 2-0 Vicryl, and the skin with a running 3-0 Prolene. Close any arthroscopy portals made outside the wound with 3-0 Prolene. Cover the wound with Steri-strips (3M, St. Paul, MN) We do not routinely place a hemovac drain. For postoperative anesthesia we inject 0.5% Marcaine (Abbot Pharmaceuticals, North Chicago, IL) into the wounds and portal regions. Apply a sterile dressing, a commercially available cryotherapy device (Iceman, djOrtho, Carlsbad, CA), and an Ace wrap (Zimmer, Dover, OH). Finally, place a hinged knee brace (TROM, djOrtho, Carlsbad, CA) locked in extension.

POSTOPERATIVE COURSE AND REHABILITATION

Patients are discharged home on the day of surgery with a 2-week supply of an oral narcotic medication and an anti-inflammatory. An aggressive physical therapy program is initiated. We allow full weight-bearing with crutches. The hinged knee brace is locked in extension for ambulation to protect the donor site. Range of motion is permitted as tolerated and immediate recovery of extension or hyperextension is emphasized. Begin heel slides, prone heel hangs, quadriceps and hamstring sets, patellar mobilizations, and straight leg raises with the hinged brace in full extension beginning the first postoperative week. The brace is used for 6 weeks. Between 2 and 4 weeks we begin weightbearing gastrocnemius and soleus stretching as well as toe raises, closed chain extension exercises, balance exercises, hamstring curls, and stationary bicycling. Usually, by 12 weeks we advance closed chain strengthening and allow straight ahead running if ROM is normal. Sport specific exercises and plyometrics are started between 4 and 6 months. Specifics of postoperative rehabilitation are discussed by McCarty and results of this technique are reviewed by Glenn in this monograph.

REFERENCES

1. Aglietti P, Buzzi R, D'Andria S, Zaccherotti G. Arthroscopic anterior cruciate ligament reconstruction with patellar tendon. *Arthroscopy* 1992;8:510–516.
2. Aglietti P. Buzzi R, Giron F, Simeone AJ, Zaccherotti G. Arthroscopic-assisted anterior cruciate ligament reconstruction with the central third patellar tendon. A 5–8-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 1997;5:138–144.
3. Bach BR, Jr, Jones GT, Sweet FA, Hager CA. Arthroscopy-assisted anterior cruciate ligament reconstruction using patellar tendon substitution. Two- to four-year follow-up results. *Am J Sports Med* 1994;22:758–767.
4. Bach BR, Jr., Levy ME, Bojchuk J, Tradonsky S, Bush-Joseph CA, Khan NH. Single-incision endoscopic anterior cruciate ligament reconstruction using patellar tendon autograft minimum two-year follow-up evaluation. *Am J Sports Med* 1998;26:30–40.
5. Bach BR, Jr., Sellards RA. Femoral aimer deformation: potential cause for altered femoral tunnel placement in anterior cruciate ligament surgery. *Arthroscopy* 2003;19:E7.
6. Bach BR, Jr., Tradonsky S, Bojchuk J, Levy ME, Bush-Joseph CA, Khan NH. Arthroscopically assisted anterior cruciate ligament reconstruction using patellar tendon autograft. Five- to nine-year follow-up evaluation. *Am J Sports Med* 1998;26:20–29.
7. Bradley JP, Klimkiewicz JJ, Rytel MJ, Powell JW. Anterior cruciate ligament injuries in the National Football League: epidemiology and current treatment trends among team physicians. *Arthroscopy* 2002;18:502–509.
8. Brown CH, Jr., Carson EW. Revision anterior cruciate ligament surgery. *Clin Sports Med* 1999;18:109–171.
9. Buss DD, Warren RF, Wickiewicz TL, Galinat BJ, Panariello R. Arthroscopically assisted reconstruction of the anterior cruciate ligament with use of autogenous patellar-ligament grafts. Results after twenty-four to forty-two months. *J Bone Joint Surg Am* 1993;75:1346–1355.
10. Carson EW, Anisko EM, Restrepo C, Panariello RA, O'Brien SJ, Warren RF. Revision anterior cruciate ligament reconstruction: etiology of failures and clinical results. *J Knee Surg* 2004;17:127–132.
11. Deehan DJ, Salmon LJ, Webb VJ, Davies A, Pinczewski LA. Endoscopic reconstruction of the anterior cruciate ligament with an ipsilateral patellar tendon autograft. A prospective longitudinal five-year study. *J Bone Joint Surg Br* 2000;82:984–991.
12. Delcogliano A, Franzese S, Branca A, Magi M, Fabbriciani C. Light and scan electron microscopic analysis of cyclops syndrome: etiopathogenic hypothesis and technical solutions. *Knee Surg Sports Traumatol Arthrosc* 1996;4:194–199.
13. Delince P, Krallis P, Descamps PY, Fabeck L, Hardy D. Different aspects of the cyclops lesion following anterior cruciate ligament reconstruction: a multifactorial etiopathogenesis. *Arthroscopy* 1998;14:869–876.
14. Hackl W, Benedetto KP, Hoser C, Kunzel KH, Fink C. Is screw divergence in femoral bone-tendon-bone graft fixation avoidable in anterior cruciate ligament reconstruction using a single-incision technique? A radiographically controlled cadaver study. *Arthroscopy* 2000;16:640–647.
15. Howell SM, Clark JA. Tibial tunnel placement in anterior cruciate ligament reconstructions and graft impingement. *Clin Orthop* 1992(283):187–195.
16. Jackson DW, Gasser SI. Tibial tunnel placement in ACL reconstruction. *Arthroscopy* 1994;10:124–131.
17. Jackson DW, Schaefer, RK. Cyclops syndrome: loss of extension following intra-articular anterior cruciate ligament reconstruction. *Arthroscopy* 1990;6:171–178.
18. Jomha NM, Pinczewski LA, Clingeleffer A, Otto DD. Arthroscopic reconstruction of the anterior cruciate ligament with patellar-tendon autograft and interference screw fixation. The results at seven years. *J Bone Joint Surg Br* 1999;81:775–779.
19. Kim HJ, Rodeo SA. Approach to meniscal tears in anterior cruciate ligament reconstruction. *Orthop Clin North Am* 2003;34:139–147.
20. Kyung HS, Ihn JC, Kim DH. Biomechanical properties after pre-twist of canine patellar tendon. *Int Orthop* 2001;25:100–103.
21. Lemos MJ, Jackson DW, Lee TQ, Simon TM. Assessment of initial fixation of endoscopic interference femoral screws with divergent and parallel placement. *Arthroscopy* 1995;11:37–41.
22. Marzo JM, Bowen MK, Warren RF, Wickiewicz TL, Altchek DW. Intraarticular fibrous nodule as a cause of loss of extension following anterior cruciate ligament reconstruction. *Arthroscopy* 1992;8:10–18.
23. Mayr HO, Weig TG, Plitz W. Arthrofibrosis following ACL

reconstruction-reasons and outcome. *Arch Orthop Trauma Surg* 2004;124:518–522.
24. Miller MD, Hinkin DT. The "N + 7 rule" for tibial tunnel placement in endoscopic anterior cruciate ligament reconstruction. *Arthroscopy* 1996;12:124–126.
25. Morgan CD, Kalman VR, Grawl DM. Definitive landmarks for reproducible tibial tunnel placement in anterior cruciate ligament reconstruction. *Arthroscopy* 1995;11:275–288.
26. Nedeff DD, Bach BR, Jr. Arthroscopic anterior cruciate ligament reconstruction using patellar tendon autografts: a comprehensive review of contemporary literature. *Am J Knee Surg* 2001;14:243–258.
27. O'Donnell JB, Scerpella TA. Endoscopic anterior cruciate ligament reconstruction: modified technique and radiographic review. *Arthroscopy* 1995;11:577–584.
28. Olszewski AD, Miller MD, Ritchie JR. Ideal tibial tunnel length for endoscopic anterior cruciate ligament reconstruction. *Arthroscopy* 1998;14:9–14.
29. Otto D, Pinczewski LA, Clingeleffer A, Odell R. Five-year results of single-incision arthroscopic anterior cruciate ligament reconstruction with patellar tendon autograft. *Am J Sports Med* 1998; 26:181–188.
30. Passler JM, Schippinger G, Schweighofer F, Fellinger M, Seibert FJ. [Complications in 283 cruciate ligament replacement operations with free patellar tendon transplantation. Modification by surgical technique and surgery timing]. *Unfallchirurgie* 1995;21: 240–246.
31. Patel JV, Church JS, Hall AJ. Central third bone-patellar tendon-bone anterior cruciate ligament reconstruction: a 5-year follow-up. *Arthroscopy* 2000;16:67–70.
32. Pierz K, Baltz M, Fulkerson J. The effect of Kurosaka screw divergence on the holding strength of bone-tendon-bone grafts. *Am J Sports Med* 1995;23:332–335.
33. Podskubka A, Kasal T, Vaculik J, Krystlik Z. [Arthroscopic reconstruction of the anterior cruciate ligament using the transtibial technique and a graft from the patellar ligament: results after 5–6 years] *Acta Chir Orthop Traumatol Cech* 2002;69:169–174.
34. Shelbourne KD, Patel DV. Timing of surgery in anterior cruciate ligament-injured knees. *Knee Surg Sports Traumatol Arthrosc* 1995;3:148–156.
35. Verma N, Noerdlinger MA, Hallab N, Bush-Joseph CA, Bach BR, Jr. Effects of graft rotation on initial biomechanical failure characteristics of bone-patellar tendon-bone constructs. *Am J Sports Med* 2003;31:708–713.
36. Webb JM, Corry IS, Clingeleffer AJ, Pinczewski LA. Endoscopic reconstruction for isolated anterior cruciate ligament rupture. *J Bone Joint Surg Br* 1998;80:288–294.