



# CHAPTER 62

## Hamstring Tendon Autograft for Anterior Cruciate Ligament Reconstruction

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The success of anterior cruciate ligament (ACL) reconstruction is influenced by many factors, such as the initial tensile properties of the graft tissue, the initial fixation of the graft, the healing at the graft fixation sites, the biologic remodeling of the graft, and the type of postoperative rehabilitation program used. Owing to its high initial tensile strength and stiffness, ability to be rigidly fixed to bone, rapid healing of bone to bone at the graft fixation sites, and outcome studies documenting predictable success in restoration of anterior knee laxity and elimination of the pivot shift phenomenon, the central-third patellar tendon autograft is considered by many surgeons to be the “gold standard” for ACL reconstruction. However, because of the well-documented donor site morbidity associated with the harvest of patellar tendon autografts, improvements in soft tissue graft fixation techniques, and clinical outcome studies demonstrating no significant difference between patellar tendon and hamstring tendon ACL reconstructions, four-stranded hamstring tendon autografts have become an increasingly popular graft choice for ACL reconstruction.\* In this chapter, we describe our current surgical technique for performing ACL reconstruction with autogenous doubled gracilis and semitendinosus tendon (DGST) grafts.

\*References 1, 2, 4, 5, 7, 12, 13, 15, 18, 22, 26, 28, 30.

### Preoperative Considerations

#### History and Physical Examination

Patients thought to have an ACL tear should provide detailed history of the initial injury and any subsequent injuries and their treatment. The diagnosis is confirmed by the Lachman and pivot shift tests or by magnetic resonance imaging if needed. It is particularly important to recognize associated injuries to the posterolateral and posteromedial structures. Failure to recognize and to treat associated patholaxity at the time of the ACL reconstruction may result in continued complaints of instability or failure of the ACL reconstruction.

#### Imaging

A preoperative anteroposterior radiograph of the involved knee in full extension and standing anteroposterior and posteroanterior 45-degree flexion views of both knees are important to rule out associated bone injury or joint space narrowing and to assess skeletal maturity of the patient. A true lateral radiograph of the injured knee in maximum hyperextension allows measurement of the intercondylar roof–femoral angle, which can be useful for preoperative

planning of the tibial tunnel in the sagittal plane. A Merchant view of both knees is helpful in assessment of patellar alignment and tilt. Full-length standing radiographs of both lower extremities from hips to ankles are indicated in patients with joint space narrowing to allow measurement of the mechanical axis. Combined or staged tibial osteotomy and ACL reconstruction may be indicated in patients with malalignment and symptoms of pain and instability.

## Indications and Contraindications

Hamstring tendon autografts are indicated for any acute or chronic ACL reconstruction. ACL reconstructions performed with hamstring tendon grafts have been shown to result in faster recovery of quadriceps muscle strength, lower incidence of donor site pain, and less interference with kneeling and crawling than after ACL reconstructions performed with patellar tendon autografts.<sup>12,18,26</sup> Because of less interference with kneeling and crawling, hamstring tendon grafts are the autogenous graft of choice for patients whose occupation, lifestyle, or religion requires “knee walking,” crawling, or kneeling. Hamstring tendon grafts are also our preferred autogenous graft for patients with a history of extensor mechanism surgery or trauma. We also prefer hamstring tendon grafts for patients with a history of patellofemoral pain or patellar tendinopathy. Finally, hamstring tendon grafts are the autogenous graft of choice when ACL reconstruction is indicated in patients with open growth plates.

The only absolute contraindication to use of hamstring tendon grafts for ACL reconstruction is previous harvest of the hamstring tendons. In cases in which prior pes anserine transfer or open surgical procedures on the medial side of the knee have been performed, the resulting scarring and alteration of normal tissue planes may complicate harvest of hamstring tendon grafts. In these situations, the surgeon may elect to use an alternative autograft or allograft tissue. Studies demonstrating a significant loss of knee flexor strength at high flexion angles suggest caution in use of hamstring tendon grafts for athletes such as gymnasts, wrestlers, sprinters, and American football defensive backs and safeties, who require maximum flexor strength at high angles of flexion.<sup>9,32</sup>

## Surgical Planning

### Graft Fixation

Rigid initial graft fixation is critical to the success of any ACL reconstruction.<sup>4</sup> Attainment of rigid initial graft fixation prevents failure and minimizes elongation at the graft fixation sites during cyclic loading of the knee before

healing at the graft fixation sites has occurred.<sup>4</sup> Because of the longer time required for hamstring tendon grafts to heal to bone, it is important to use graft fixations that are strong and stiff and that resist slippage under cyclic loading, to prevent the development of progressive laxity in the postoperative period. However, at present, the optimal graft fixation method for hamstring tendon grafts remains controversial, and there is little consensus as to what fixation methods produce the best clinical outcomes.

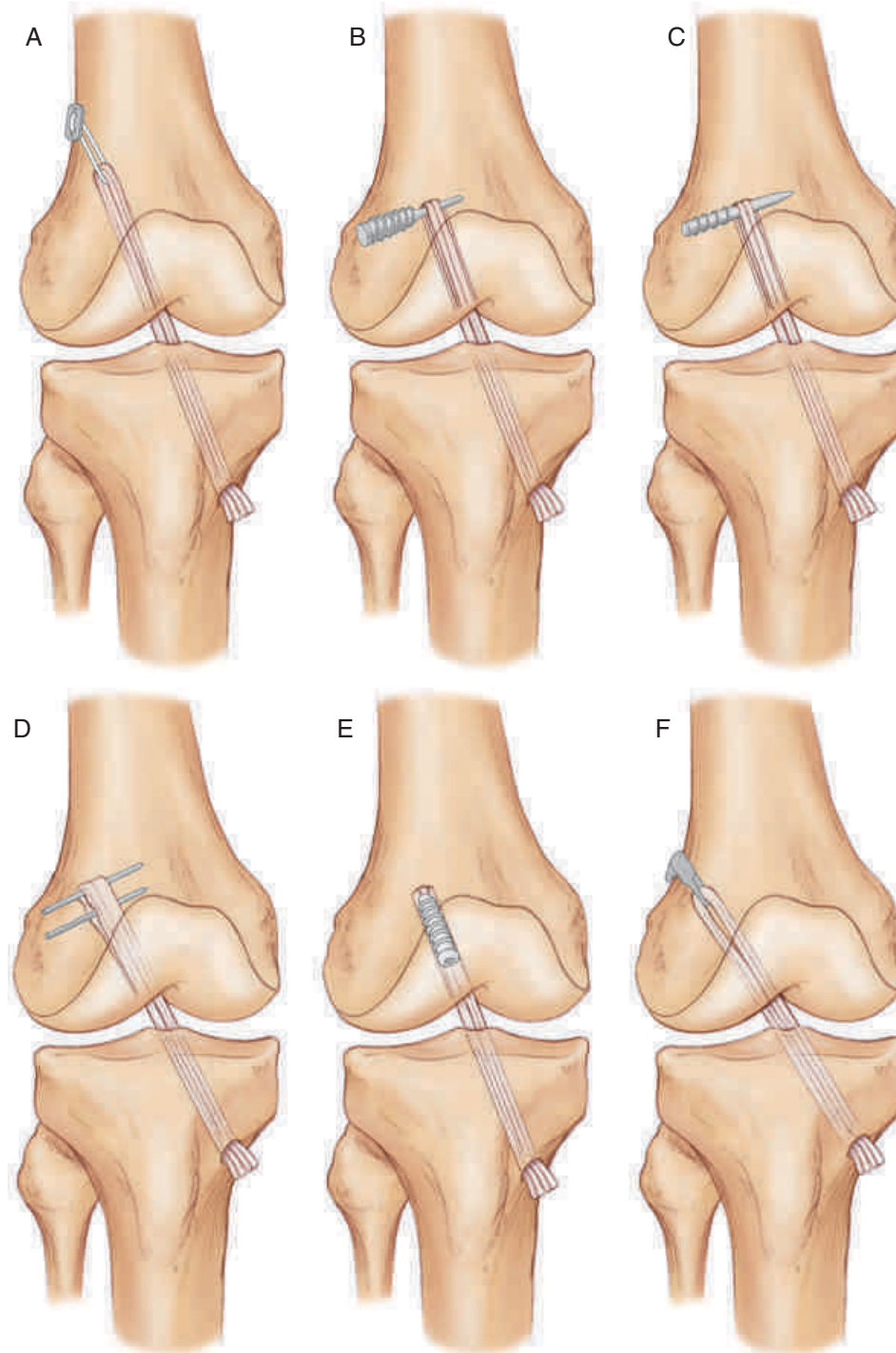
### Femoral Fixation Options (Fig. 62-1)

Laboratory biomechanical studies have demonstrated that the EndoButton CL and cross pins provide strong femoral fixation with minimal slippage during cyclic loading.<sup>6,19</sup> Although intertunnel fixation with interference screws is a popular hamstring tendon graft fixation technique, our laboratory biomechanical studies have demonstrated that this fixation method is the weakest and has the largest amount of slippage during cyclic loading.<sup>6,19</sup> We prefer femoral fixation with the EndoButton CL for the following reasons:

- Fixation strength is high.
- Slippage during cyclic loading is minimal.
- The fit of the tendon in the bone tunnel is tight.
- The 360 degrees of contact between the bone tunnel wall and the hamstring tendon graft enhances healing.
- The amount of graft inserted into the femoral tunnel can be customized.
- Removal of the implant is not required in revision cases.
- Fixation properties are not dependent on the bone quality of the distal femur.

### Tibial Fixation Options (Fig. 62-2)

Tibial fixation is the weak link of ACL graft fixation, and tibial fixation of hamstring tendon grafts remains problematic.<sup>4</sup> Problems with tibial fixation result primarily from the lower bone mineral density of the proximal tibia and the fact that tibial fixation devices must resist shear forces applied parallel to the axis of the tibial bone tunnel.<sup>4</sup> Cortical fixation techniques can address the issue of the lower bone mineral density of the proximal tibia. However, these implants are often prominent and may cause local skin irritation and pain and require a second operation for removal.<sup>24</sup> Intratunnel tibial fixation with interference screws eliminates the problem of prominent hardware; however, laboratory biomechanical studies have shown that this fixation method is the weakest and demonstrates



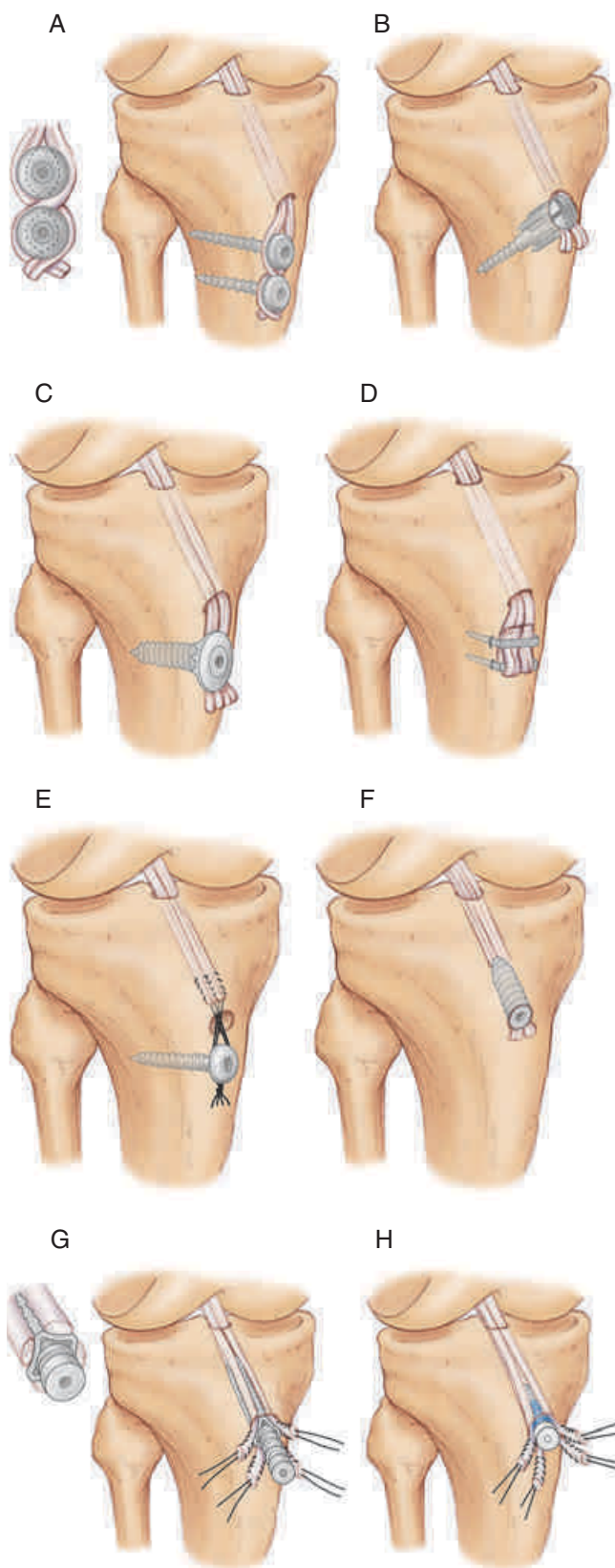
**Figure 62-1** Femoral fixation options. **A**, EndoButton CL. **B**, Bone Mulch screw. **C**, TransFix. **D**, RigidFix. **E**, Bioabsorbable screw. **F**, EZLoc.

the greatest amount of slippage under cyclic loading.<sup>20,24</sup> On the basis of its ease of use and of biomechanical studies that demonstrate high initial fixation strength and stiffness with minimal slippage under cyclic loading conditions, we prefer intertunnel tibial fixation with the IntraFix tibial fastener (DePuy-Mitek, Norwood, Mass).<sup>7,19</sup>

## Surgical Technique

### Anesthesia and Positioning

The operation is performed as an outpatient procedure under general or regional anesthesia. A thigh-length TED



**Figure 62-2** Tibial fixation options. **A**, AO ligament washers. **B**, WasherLoc. **C**, Spiked ligament washer. **D**, Staples. **E**, Suture-post fixation. **F**, Bioabsorbable screw. **G**, IntraFix tibial fastener. **H**, GTS sleeve and tapered screw.

antiembolism stocking (Kendall Company, Mansfield, Mass) and a foam rubber heel pad are applied to the well leg. A padded pneumatic tourniquet is applied high on the thigh of the operative leg but is rarely used during the operation. The patient is positioned supine on the operating room table and given 1 g of a first-generation cephalosporin intravenously followed by a continuous intravenous infusion of ketorolac at 4 mg/hr. A lead gonad shield is applied to protect the patient from radiation exposure during intraoperative fluoroscopy. Our preferred technique is to position the lower extremity so that a full, free range of motion can be performed during the procedure. Full unrestricted flexion of the knee is particularly important if the femoral tunnel is drilled by the anteromedial portal technique. We use a padded thigh post and hip positioner placed at the level of the tourniquet and a padded, L-shaped footrest that can be moved along the side rail of the operating room table, allowing the flexion angle of the knee to be changed during the procedure. The padded footrest is typically adjusted to maintain the knee at 90 degrees of flexion without manual assistance. The padded hip positioner stabilizes the patient's pelvis and the padded thigh post acts as a fulcrum to allow application of valgus force to the knee, permitting the medial compartment to be opened for performance of meniscus surgery (Fig. 62-3). Use of a standard circumferential arthroscopic leg holder and dropping the foot of the operating room table limit knee flexion and may compromise drilling of the femoral tunnel by the anteromedial portal technique.

After routine iodine skin preparation and sterile draping, a solution of 5 mg of morphine sulfate plus 20 mL of 0.25% bupivacaine (Marcaine) with 1:100,000 epinephrine is injected into the suprapatellar pouch for pre-emptive analgesia. With the use of a continuous ketorolac intravenous infusion and intra-articular administration of morphine, we have not found it necessary to use femoral nerve blocks for postoperative pain management. Use of an infusion pump improves joint distention and visualization, allowing the procedure to be performed without inflation of the tourniquet.

### Specific Steps (Box 62-1)

#### 1. Hamstring Tendon Graft Harvest

Harvest of the hamstring tendons can be performed through a vertical or oblique skin incision centered over the tibial insertion of the pes anserine tendons (Fig. 62-4). When the transtibial tunnel technique is used to drill the femoral tunnel, it is important to center the vertical skin incision midway between the anterior tibial crest and the posteromedial border of the tibia to allow the tibial tunnel to be positioned along the anterior fibers of the medial collateral ligament (MCL). If the femoral tunnel is to be drilled by the anteromedial portal technique, the vertical



A

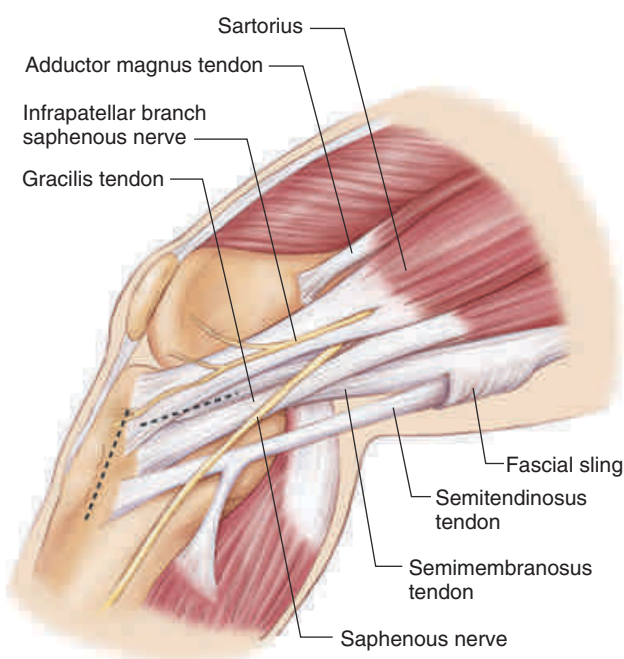


B

**Figure 62-3** **A**, The padded thigh post and L-shaped footrest allow the knee to be positioned at 90 degrees of flexion without manual assistance. **B**, The thigh post allows full, unrestricted knee flexion during the procedure.

**Box 62-1** Surgical Steps

1. Hamstring tendon graft harvest
2. Graft preparation
3. Arthroscopic portal placement
4. Preparation of the intercondylar notch
5. Femoral tunnel
6. Tibial tunnel
7. Calculation of EndoButton CL length and graft preparation
8. Graft passage and femoral fixation
9. Graft tensioning
10. Tibial fixation
11. Closure



**Figure 62-4** Hamstring tendon graft harvest skin incisions and anatomic relationships on the medial side of the knee. A vertical or an oblique skin incision can be used to harvest the hamstring tendons. Important features to note are the proximity of the vertical incision to the infrapatellar branches of the saphenous nerve, the proximity of the oblique incision to the saphenous nerve, the relationship of the saphenous nerve to the gracilis tendon, the fascial connection between the medial head of the gastrocnemius, and the fascial sling that suspends the semitendinosus tendon beneath the semimembranosus muscle. (From Brown CH, Sklar JH, Darwich N. Endoscopic anterior cruciate ligament reconstruction using autogenous doubled gracilis and semitendinosus tendons. *Tech Knee Surg* 2004;3:217.)

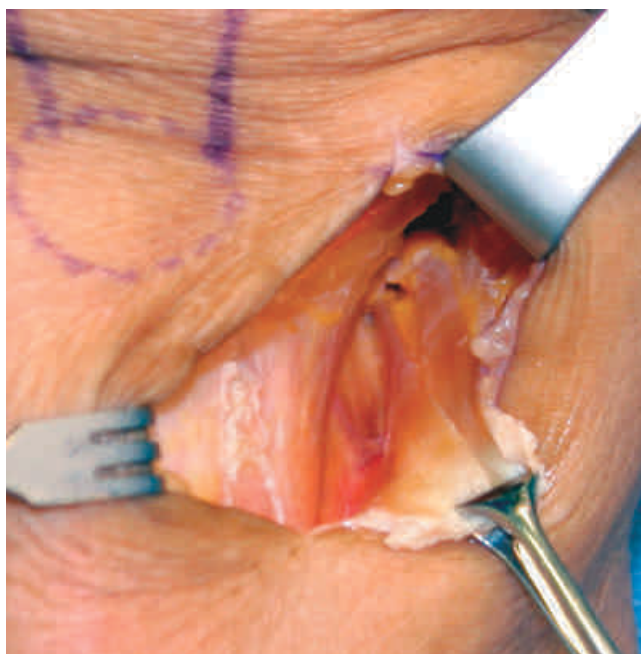
skin incision can be positioned closer to the anterior crest of the tibia. This incision is more extensile and can easily be extended to harvest a patellar tendon graft should premature amputation of the semitendinosus tendon graft occur. The oblique skin incision runs parallel to Langer's

lines (resulting in a more cosmetic appearance), provides better proximal exposure of the tendons, and requires less skin retraction during drilling of the tibial tunnel. The anatomic course of the infrapatellar branches of the saphenous nerve also makes them less vulnerable to injury when the oblique skin incision is used.<sup>31</sup> However, the saphenous nerve can be injured if the oblique skin incision is positioned too close to the posteromedial corner of the tibia or sharp dissection is extended back into this region.<sup>31</sup> Should premature amputation of the semitendinosus tendon occur, the oblique skin incision is not extensile and an additional skin incision is required to harvest a patellar tendon autograft. We recommend against use of the oblique skin incision until experience is gained with the harvesting technique and the surgeon is able to consistently harvest hamstring tendon grafts of adequate length.

In the average-size patient, the superior border of the sartorius tendon is approximately one finger width below the tibial tubercle or three finger widths below the medial joint line (personal observation: the tendons insert more proximally in Middle Eastern patients). In revision cases involving a failed primary patellar tendon reconstruction, the distal portion of the previous patellar tendon harvest incision can be extended distally 2 to 3 cm below the tibial tubercle, allowing simultaneous harvest of the hamstring tendon grafts and removal of the tibial fixation hardware.

The skin incision and subcutaneous tissues are infiltrated with a solution of 0.25% bupivacaine with 1 : 100,000 epinephrine for hemostasis and pre-emptive analgesia. We routinely harvest the tendon grafts without inflation of the tourniquet. The sartorius fascia is exposed by sharp and blunt dissection. We use an inside-out technique to harvest the two tendons because this technique gives an excellent view of the internal aspect of the pes anserine and allows the surgeon to better visualize and to identify any of the associated anatomic variations or variable tendon attachments to the tibia, which are common.<sup>21</sup> In the inside-out technique, the conjoint tibial insertion of the two tendons is detached from the tibia by making an inverted L-shaped incision through the sartorius fascia. The sartorius fascia is grasped with an Allis clamp and lifted away from the tibia, thus protecting the underlying MCL. The fascia is incised parallel to the gracilis tendon and the tibial insertion of the two tendons is sharply released from the crest of the tibia, revealing the inner aspects of the two tendons (Fig. 62-5).

A right-angled type clamp is used to separate the two tendons from the undersurface of the sartorius fascial flap, which is preserved for later closure. The gracilis tendon is sharply divided and grasped with wide Allis-Adair tissue forceps (Codman & Shurtleff, Inc., Raynham, Mass). Blunt scissors dissection is used to free the tendon from the undersurface of the sartorius fascia. It is important to bluntly release the interconnecting fascial bands that run

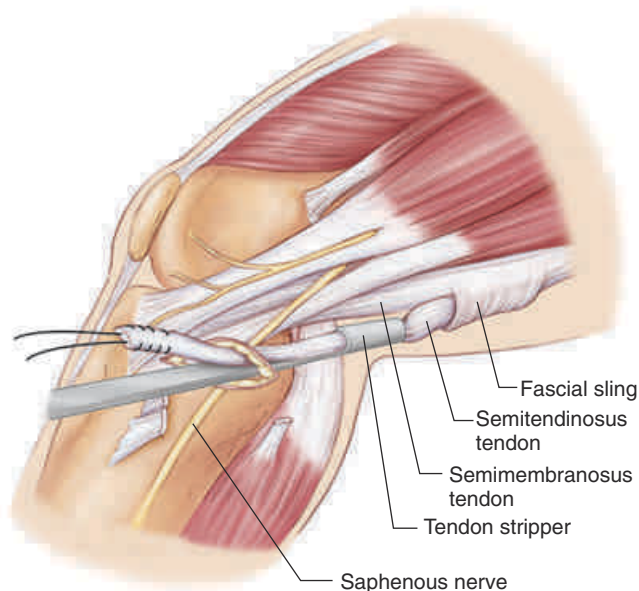


**Figure 62-5** The inverted L-shaped fascial flap is reflected distally, exposing the deep aspect of the two tendons.

between the two tendons. Sharp or scissors dissection along the superior border of the gracilis should be avoided to prevent injury to the saphenous nerve, which leaves Hunter canal and crosses over the superior border of the gracilis tendon at the posteromedial corner of the knee.<sup>31</sup> Five throws of a running baseball-style whipstitch are placed in the free end of the gracilis tendon with a No. 2 nonabsorbable suture (Ti+Cron, United States Surgical, Norwalk, Conn; Ethibond special order D-5757, Ethicon, Inc., Somerville, NJ).

Depending on the surgeon's preference, the tendons can be harvested with a slotted tendon stripper, a closed Brand-type tendon stripper, or a tendon harvester (Linvatec, Largo, Fla). The gracilis tendon is harvested by flexing the knee to 90 degrees and advancing the tendon stripper parallel to the tendon by a slow, steady, rotating motion. The semitendinosus tendon is harvested in a similar fashion; however, there are more extensive fascial connections that extend from the inferior border of the semitendinosus tendon to the medial head of the gastrocnemius.<sup>7,31</sup> These fascial connections must be released to prevent premature amputation of the semitendinosus tendon.

More proximally in the thigh, the surgeon may encounter a second potential troublesome area at a band of thickened semimembranosus fascia that courses inferior and medial to the semimembranosus tendon.<sup>7</sup> This thickened band of fascia forms a sling for the semitendinosus tendon, suspending it from the inferior border of the semimembranosus muscle. Premature amputation of the semitendinosus tendon can result if the tendon strip-



**Figure 62-6** Passage of the tendon stripper outside of the fascial sling beneath the semimembranosus muscle may result in the tendon stripper's taking an aberrant path into the thigh and causing premature amputation of the semitendinosus graft. (From Brown CH, Sklar JH. Endoscopic anterior cruciate ligament reconstruction using quadrupled hamstring tendons and EndoButton femoral fixation. *Tech Orthop* 1998;13:285.)

per passes outside of the tendon's normal path (Fig. 62-6).<sup>7</sup> If excessive resistance is encountered in attempting to advance the tendon stripper through this region, it is tempting to pull harder on the semitendinosus tendon and to apply more force to the tendon stripper to advance it. However, this can cause the fascial sling beneath the semimembranosus to constrict, making it more difficult to pass the tendon stripper. Decreasing tension on the tendon and "navigating" the tendon stripper through the fascial sling will often lead to success. In a heavily muscled individual, the tendon stripper will often meet resistance at the musculotendinous junction; this can be overcome by steady pressure and rotation of the tendon stripper or by use of the larger 7.4-mm diameter stripper (Smith & Nephew Endoscopy, Andover, Mass). A successful graft harvest typically results in graft lengths of 20 to 26 cm for the gracilis and 24 to 30 cm for the semitendinosus tendon.

## 2. Graft Preparation

Preparation of the hamstring tendon grafts is facilitated by use of a graft preparation board (Graft Master II; Smith & Nephew Endoscopy). Residual muscle fibers on the proximal end of both tendons are removed by blunt dissection with a metal ruler, a large curet, or a Cushing-type periosteal elevator. The two tendons are cut to the same length, and the proximal end of each tendon is tubularized with a running, baseball-style whipstitch of a No. 2 nonabsorbable suture. The sutures on each end of the tendon grafts are tensioned with a "cinching" motion to remove excess slack



**Figure 62-7** Doubled gracilis and semitendinosus tendon (DGST) graft. (From Brown CH, Sklar JH, Darwich N. Endoscopic anterior cruciate ligament reconstruction using autogenous doubled gracilis and semitendinosus tendons. *Tech Knee Surg* 2004;3:221.)

from the whipstitches. The two tendon grafts are looped around a No. 5 suture, making a DGST graft (Fig. 62-7). The diameter of the DGST graft is measured to the nearest 0.5 mm by use of a 0.5-mm incremental sizing block or sizing tubes. The whipstitches from the gracilis and semitendinosus tendons on each end of the graft are tied together approximately 12 cm from the end of the tendon grafts. This facilitates use of a graft-tensioning device later in the procedure. The DGST graft is looped around an EndoButton tensioning post (Smith & Nephew Endoscopy), and the DGST graft is covered with a moist laparotomy pad and pretensioned on the graft preparation board with 5 to 10 pounds for the remainder of the procedure.

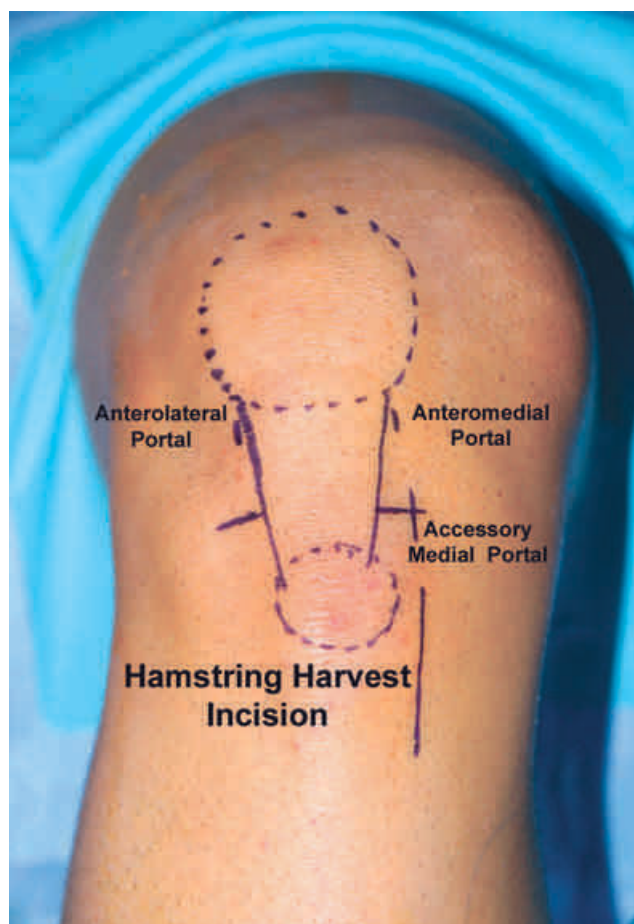
### 3. Arthroscopic Portal Placement

As recommended by Cohen and Fu,<sup>10</sup> we use three portals for ACL reconstruction (Fig. 62-8). A high anterolateral portal at the level of the inferior pole of the patella adjacent to the lateral border of the patellar tendon is used for the routine viewing portal. The height of this portal places the arthroscope above the fat pad and provides an excellent “look down” view of the ACL tibial attachment site. This portal gives a frontal view of the femoral attachment site of the ACL and is most helpful in determining the clock orientation and high-low placement of the femoral tunnel. An anteromedial portal at the level of the inferior pole of the patella adjacent to the medial border of the patellar tendon is used for instrumentation and viewing of the medial wall of the lateral femoral condyle. This portal provides a more orthogonal view of the ACL femoral attachment site and allows more accurate assessment of shallow-deep femoral tunnel placement (Fig. 62-9).

An accessory medial portal located directly inferior to the anteromedial portal at the level of the medial joint line is used for drilling of the femoral tunnel.

### 4. Preparation of the Intercondylar Notch

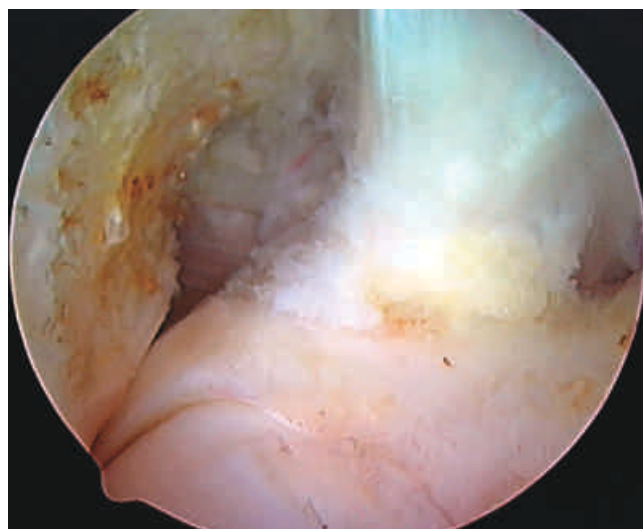
Preparation of the intercondylar notch is necessary to allow visualization of the ACL femoral attachment site. A



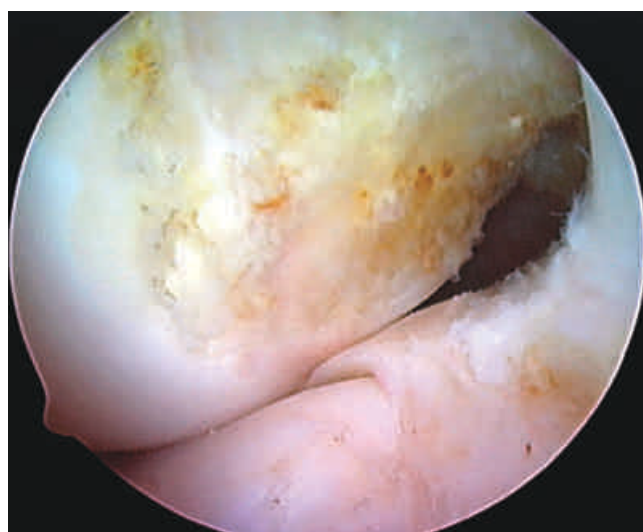
**Figure 62-8** Portal location (right knee).

routine diagnostic arthroscopy is performed, and associated meniscal and chondral injuries are treated appropriately. The torn fibers of the ACL are removed from the lateral femoral condyle and the tibial attachment site by a motorized shaver, electrocautery pencil, or radiofrequency





A



B

**Figure 62-9** Arthroscopic view of femoral attachment site of the ACL from the anterolateral portal (A) and the anteromedial portal (B).

probe. We have found that use of a radiofrequency probe is faster, allows hemostasis to be achieved, and more completely removes the soft tissue along the lateral wall of the intercondylar notch, providing better visualization of the bone anatomy. Use of the anteromedial portal technique allows the femoral tunnel to be positioned lower down the sidewall of the lateral femoral condyle, resulting in a more horizontal orientation of the ACL graft. A more horizontal ACL graft avoids posterior cruciate ligament impingement and in most cases eliminates the need for notchplasty. However, a selective notchplasty may be required in the case of congenitally narrowed notches or in chronic cases with notch stenosis due to the development of notch osteophytes.

### Transtibial Tunnel Technique Versus Anteromedial Portal Technique

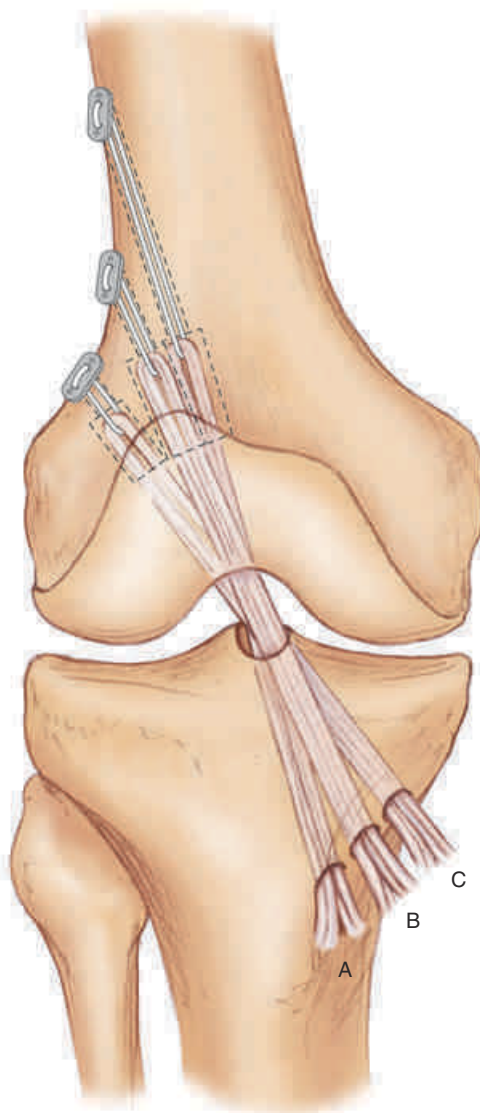
Hamstring ACL reconstruction can be performed by the transtibial tunnel or anteromedial portal technique.<sup>7,22,25,26,29</sup> Regardless of the surgical technique used, the following goals must be achieved to optimize the outcome of the procedure:

- An anatomically positioned, impingement-free tibial tunnel
- A tibial tunnel with a minimum length of 40 mm
- An orientation of the femoral tunnel at a 9:30- to 10-o'clock position along the sidewall of the lateral femoral condyle
- A femoral tunnel with a minimum length of 40 mm

Achievement of these goals will eliminate roof impingement, optimize graft fixation with the EndoButton CL and IntraFix tibial fastener, and maximize the ability of a single-tunnel hamstring ACL reconstruction to control tibial rotation.<sup>23</sup>

Advantages of the transtibial tunnel technique are that it is familiar to most surgeons and does not require the knee to be flexed to 120 degrees during drilling of the femoral tunnel. Joint distention and the field of view in the intercondylar notch are compromised when the knee is flexed to 120 degrees or more, as required with the anteromedial technique. The transtibial tunnel technique also tends to produce longer femoral tunnels in the range of 40 to 50 mm. Femoral tunnel lengths in this range are advantageous for the EndoButton CL fixation technique because they allow a minimum of 25 mm of DGST graft to be inserted into the femoral socket. Another advantage of the transtibial tunnel technique is that the length of the femoral tunnel typically results in the EndoButton implant's resting on the stronger cortical bone of the distal femur. The major disadvantage of the transtibial tunnel technique is that free positioning of the femoral tunnel in the intercondylar notch is not possible because the femoral tunnel location is determined by the axis of the tibial tunnel.

In the transtibial tunnel technique, the angle of the tibial tunnel in the coronal plane determines femoral tunnel length and the position of the ACL graft in the intercondylar notch (Fig. 62-10).<sup>7</sup> Laboratory biomechanical studies have demonstrated that single-tunnel ACL grafts placed at the 10-o'clock position provide better rotational control as compared with ACL grafts at the 11-o'clock position.<sup>23</sup> For the femoral tunnel to be positioned at the 10-o'clock location, the tibial guide pin must be started adjacent to the anterior fibers of the MCL<sup>7</sup> (Fig. 62-11). However, in some cases, even when these recommendations are followed, it may not be possible to place the femoral tunnel at the desired position. When faced with this situation, we recommend switching to the anteromedial portal technique to avoid malpositioning of the



**Figure 62-10** Effect of tibial tunnel starting position on femoral tunnel length. Tibial tunnel starting position close to the tibial tubercle (A) results in a long, vertically oriented femoral tunnel that requires a long continuous-loop length. A long continuous loop decreases stiffness of the femur–EndoButton CL–hamstring tendon complex. Tibial tunnel starting position midway between the tibial tubercle and the anterior fibers of the MCL (B) typically results in a femoral tunnel length of 50 to 60 mm. Tibial tunnel starting position at the anterior fibers of the MCL (C) typically results in a femoral tunnel length of 40 to 50 mm. (From Brown CH, Sklar JH. Endoscopic anterior cruciate ligament reconstruction using quadrupled hamstring tendons and EndoButton femoral fixation. *Tech Orthop* 1998;13:288.)

ACL graft. For a detailed description of hamstring ACL reconstruction performed by the transtibial tunnel technique, we refer the reader to our previously published technique.<sup>7</sup>

In the anteromedial portal technique, the femoral tunnel is drilled through the anteromedial portal or an accessory anteromedial portal.<sup>23,29</sup> Because the femoral tunnel is made independently of the tibial tunnel, free placement in the intercondylar notch is always possible.

Advantages of the anteromedial portal technique include the following:

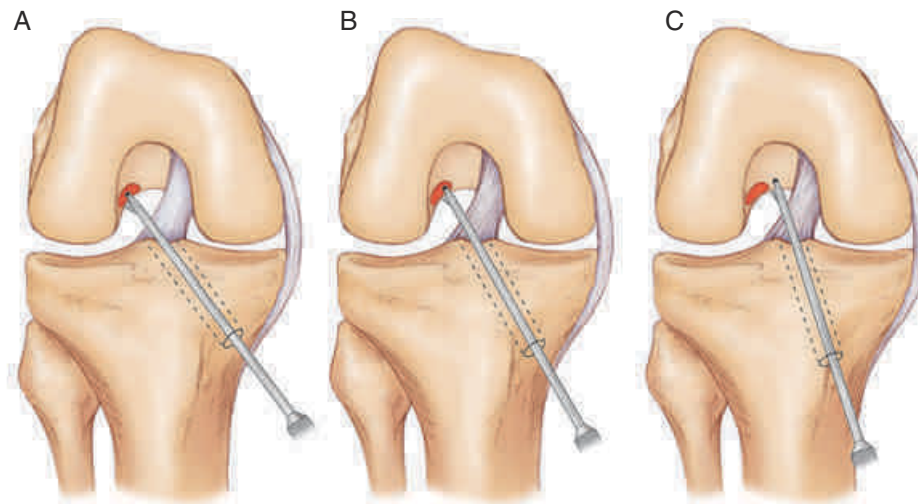
- The ability to position the femoral tunnel in a more anatomic position lower down the sidewall of the lateral femoral condyle
- The freedom to locate the starting position of the tibial tunnel anywhere along the medial surface of the tibia
- The freedom to drill a steeper and therefore longer tibial tunnel
- The possibility of drilling the femoral tunnel before drilling the tibial tunnel, which helps maintain joint distention, improving joint visualization during the remainder of the procedure

However, the anteromedial portal technique requires the knee to be flexed 120 degrees or more during the drilling of the femoral tunnel, which limits joint distention and provides a more unconventional field of view in the notch that can result in spatial disorientation.<sup>23,29</sup> The anteromedial portal technique also tends to produce a more horizontal femoral tunnel that results in the EndoButton implant's lying on the weaker metaphyseal bone of the distal femur.<sup>8</sup> In our opinion, the ability of the anteromedial portal technique to allow a more anatomic placement of the femoral tunnel far outweighs its few disadvantages. For this reason, the anteromedial portal technique for femoral tunnel drilling has become our preferred surgical technique for performing ACL reconstruction.

### 5. Femoral Tunnel

Use of the low accessory medial portal for drilling of the femoral tunnel allows a longer femoral tunnel to be achieved than does drilling through the anteromedial portal. The resulting longer femoral tunnel is more advantageous for femoral fixation with the EndoButton CL. The location for the accessory medial portal is made by an 18-gauge spinal needle. This portal is located as low as possible just above the medial joint line. Placement of the portal too medially produces a shorter femoral tunnel and risks injury to the medial femoral condyle by the endoscopic drill bit during drilling of the femoral tunnel. The accessory medial portal is established under direct vision with a No. 11 knife blade, with care taken to avoid injury to the medial meniscus. Dilation of the portal with the blunt arthroscope obturator followed by the tips of the Metzenbaum scissors helps ease future passage of instrumentation.

A microfracture awl is passed through the accessory medial portal and used to mark the starting point for the femoral tunnel under arthroscopic guidance. Correct placement of the awl along the lateral wall of the intercondylar notch can be verified by intraoperative fluoroscopy with the radiographic quadrant method.<sup>3</sup> Fine tuning of



**Figure 62-11** **A**, Tibial tunnel starting position at the anterior fibers of the MCL results in a femoral starting point at the 10-o'clock position (central portion of the ACL footprint). **B**, Tibial tunnel starting position midway between the anterior fibers of the MCL and the tibial tubercle results in a femoral starting point at the 11-o'clock position (attachment site of the anteromedial fibers). **C**, Tibial tunnel starting position close to the tibial tubercle results in a femoral starting point high in the intercondylar notch outside of the ACL footprint. (Redrawn from Brown CH, Sklar JH, Darwich N. Endoscopic anterior cruciate ligament reconstruction using autogenous doubled gracilis and semitendinosus tendons. *Tech Knee Surg* 2004;3:222.)

the awl's position is performed under fluoroscopic guidance. Additional confirmation of the correct starting point can be made by viewing the tip of the awl through the anteromedial portal (Fig. 62-12).

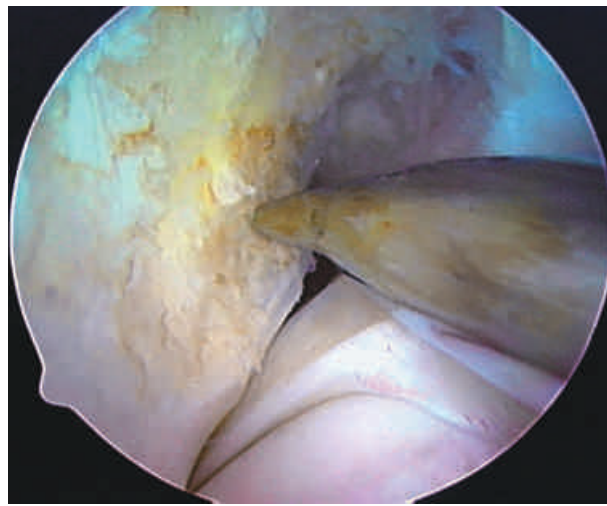
A 4- or 5-mm offset femoral aimer is passed through the accessory medial portal, and the knee is slowly flexed to 120 degrees. The blade of the femoral offset aimer is placed in the over-the-top position, and a 2.7-mm drill-tipped guide pin is positioned at the site of the microfracture awl penetration mark. Fluoroscopy can be used to check the guide pin placement. The knee is slowly brought into full flexion, and line of sight is used to verify that the guide pin will exit the lateral thigh above the intermuscular septum. The 2.7-mm drill-tipped guide wire is drilled out through the soft tissues of the lateral thigh (Fig. 62-13). Inadequate knee flexion can result in the guide pin's coming to lie inferior to the intermuscular septum, placing the peroneal nerve at risk. A 4.5-mm EndoButton drill bit (Smith & Nephew Endoscopy) is used to drill a channel through the lateral femoral cortex. A closed-end femoral socket is drilled with the appropriately sized, calibrated endoscopic 0.5-mm drill bit (Fig. 62-14). The femoral socket depth must allow for the length of the DGST graft to be inserted into the femur (usually 25 to 30 mm) plus an extra 6 mm to allow the EndoButton to clear the lateral femoral cortex and to flip. An EndoButton depth gauge (Smith & Nephew Endoscopy) inserted through the accessory medial portal is used to measure the femoral tunnel length. A loop of No. 5 nonabsorbable suture is inserted into the eyelet of the passing pin, and the ends of the suture are passed out of the lateral thigh. The loop of No. 5 suture is passed into the joint and positioned at the entrance to the femoral tunnel. This suture will be used later in the

procedure to pass the hamstring tendon graft. Because cylindrical hamstring tendon grafts contact the entire edge of the femoral tunnel during cyclic motion of the knee, it is extremely important to bevel or chamfer the tunnel edges with a rasp to minimize graft abrasion.

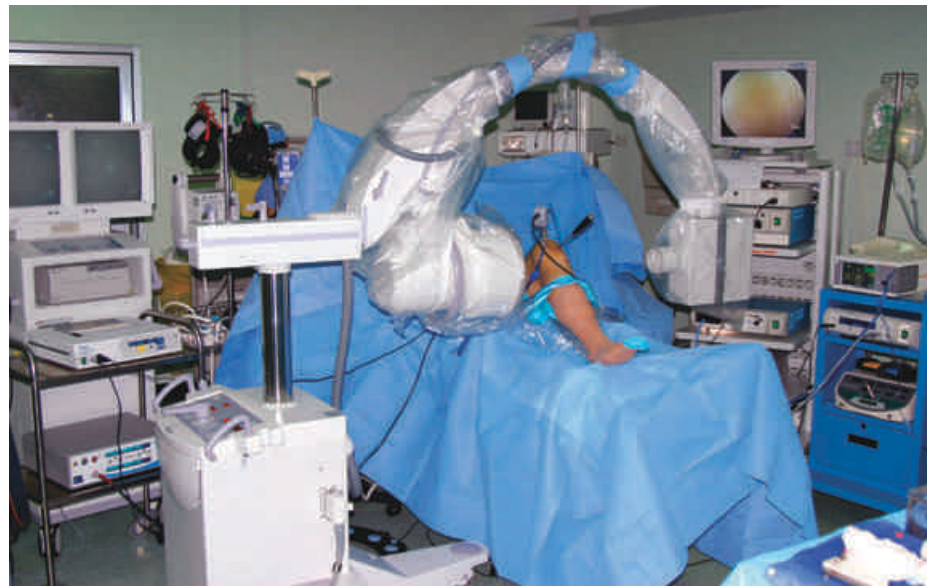
## 6. Tibial Tunnel

In our surgical technique, a tibial tunnel length of 40 to 50 mm is optimal; this range will allow the 30-mm-long IntraFix sheath to be inserted flush with the tibial cortex, with no risk that the sheath will protrude into the intra-articular portion of the knee joint. Setting the adjustable tibial aimer between 50 and 55 degrees will usually allow these tunnel lengths to be achieved. The starting location of the tibial guide pin along the medial surface of the tibia is not critical when the anteromedial portal technique is used. The anterior horn of the lateral meniscus, the medial and lateral tibial spines, and the posterior cruciate ligament are used as landmarks to locate the intra-articular position of the tibial guide pin (Fig. 62-15). It is extremely helpful to use fluoroscopy to ensure correct placement of the tibial guide pin. With the knee in maximum extension, a true lateral fluoroscopic view of the knee with the femoral condyles overlapping is obtained. The tip of the guide pin should be parallel to and 2 mm posterior to Blumensaat's line (Fig. 62-16). An offset parallel drill guide can be used to reposition the guide pin if necessary. To prevent anterior drift of the tibial tunnel, a cannulated, rear-entry-style, 0.5-mm drill bit is used to drill the tibial tunnel. Half-round or angled ACL chamfering rasps are used to smooth the intra-articular edges of the tibial tunnel to minimize graft abrasion. Soft tissue around the superior edge of the

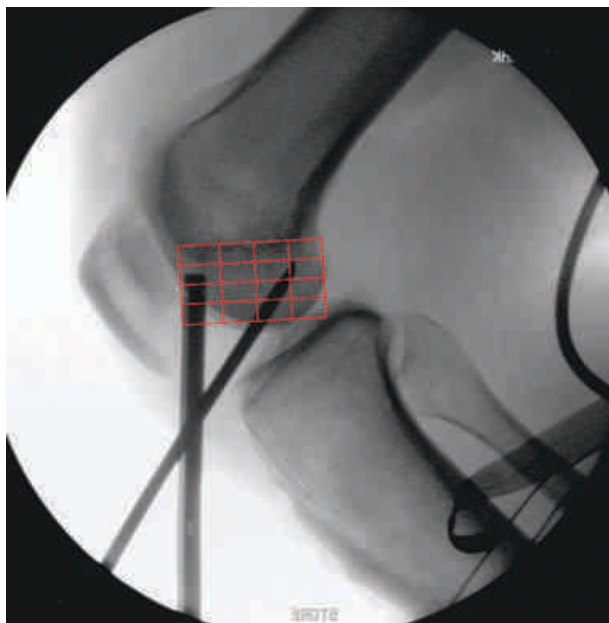
*Text continued on p. 633.*



A



B

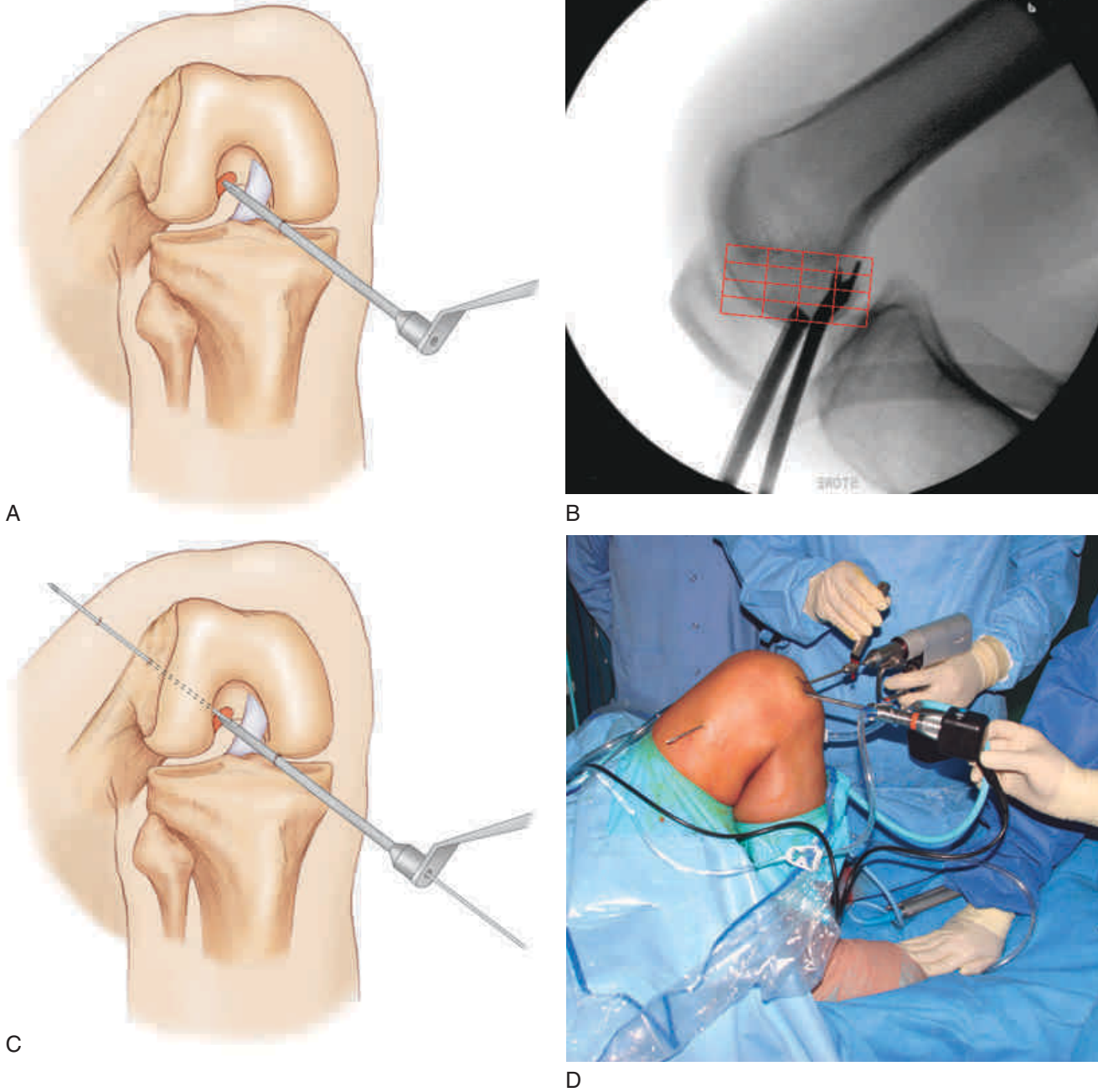


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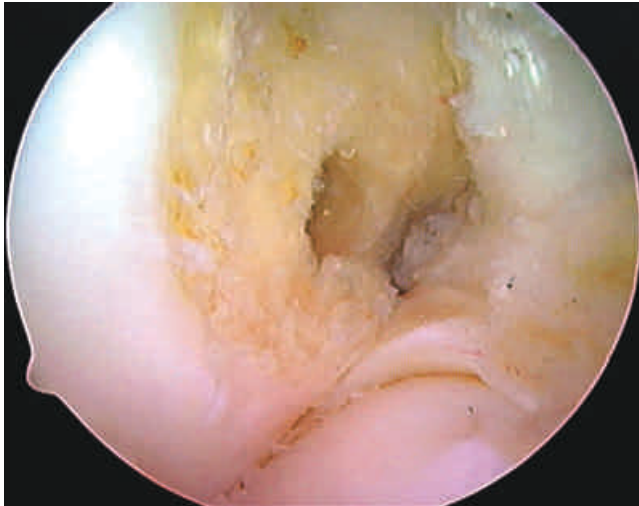


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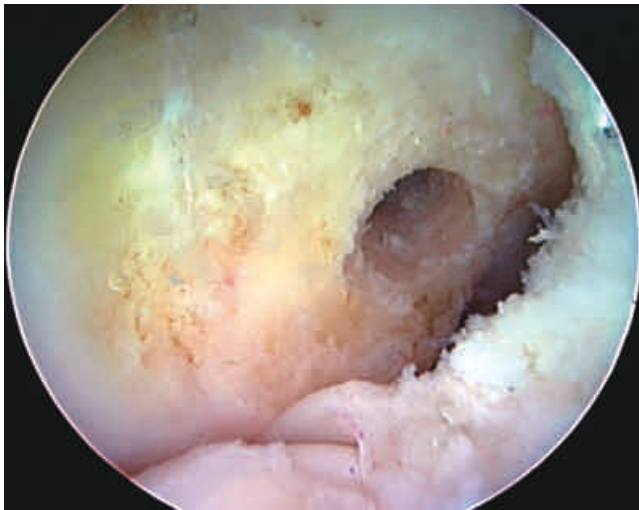
**Figure 62-12** **A**, Microfracture awl introduced through the accessory medial portal is used to establish a starting point for the femoral tunnel (view through the anterolateral portal). **B**, Fluoroscopy is used to orient the starting point for the femoral tunnel. **C**, Digital fluoroscopic images can be captured with an Image Capture System. The radiographic quadrant of Bernard et al<sup>3</sup> can be used to determine the optimal starting point for the femoral tunnel. According to this method, the starting point for the femoral guide pin should be in the distal corner of the posterior superior quadrant. **D**, Fine adjustments of the starting point can be made by viewing the awl through the anteromedial portal. Viewing through this portal gives better shallow-deep spatial orientation in the notch.



**Figure 62-13** **A**, Femoral offset aimer is introduced through the accessory medial portal; the tip of the aimer is positioned at the previously marked starting point. **B**, Fluoroscopy can be used to confirm the starting point for the femoral guide pin. **C** and **D**, The femoral guide pin is drilled out through the lateral soft tissues with the knee in full flexion.

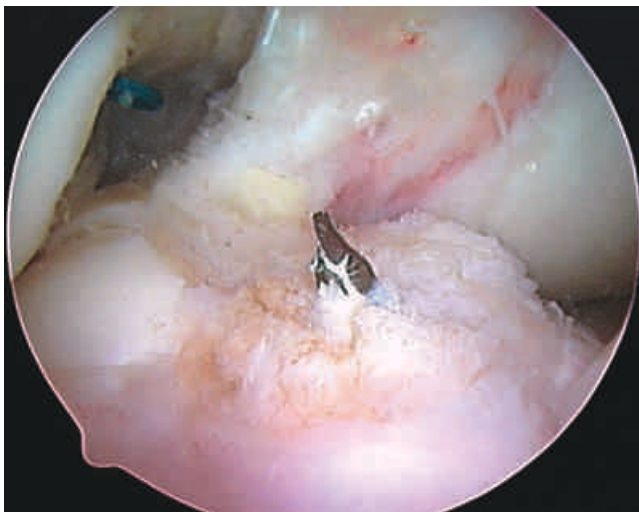


A



B

**Figure 62-14** **A**, Femoral tunnel viewed through the anterolateral portal with the knee at 90 degrees of flexion. **B**, Femoral tunnel viewed through the anteromedial portal with the knee at 90 degrees of flexion.



**Figure 62-15** The tibial guide pin should be positioned halfway between the medial and lateral tibial spines along a line connecting the anterior horn of the lateral meniscus and the medial tibial spine.



A



B

**Figure 62-16** **A**, To ensure correct placement of the tibial guide pin, fluoroscopy is used to obtain a true lateral view with the knee in maximum hyperextension. **B**, The guide pin should lie 2 mm posterior to and parallel to Blumensaat's line.

tibial tunnel is cleared with an electrocautery pencil and a Cobb periosteal elevator in preparation for insertion of the IntraFix tibial fastener.

### 7. Calculation of EndoButton CL Length and Graft Preparation

The required continuous-loop length is calculated by subtracting the amount of graft to be inserted into the femoral socket from the directly measured femoral tunnel length. For example, assuming the femoral tunnel length measures 48 mm, and 30 mm of DGST graft has been chosen to be inserted into the femoral tunnel, the required continuous-loop length is calculated as follows: 48 mm – 30 mm = 18 mm. Because the continuous-loop lengths come in 5-mm increments, a 15- or 20-mm-loop comes closest to the calculated length. In general, we prefer to use the shortest possible continuous loop because this increases the stiffness of the femur–EndoButton CL–DGST graft complex. In the example cited before, we would choose a 15-mm length of loop. The appropriate length of EndoButton CL is selected and placed in the EndoButton holder (Smith & Nephew Endoscopy), and the axilla of the DGST graft is passed through the continuous loop. The two ends of the DGST graft are equalized in length and pretensioned to 10 pounds on the graft preparation board. The graft is marked with a surgical marking pen at the measured femoral tunnel length. A full-length No. 2 flipping suture and a No. 5 passing suture are passed through the end holes of the EndoButton. A second No. 5 suture can be inserted into the same hole as the No. 2 flipping suture and passed alongside the graft and out of the tibial tunnel. If necessary, this “safety suture” can be used to disengage the EndoButton from the distal femur, allowing the hamstring tendon graft to be removed from the knee.

### 8. Graft Passage and Femoral Fixation

The loop of No. 5 suture is retrieved from the femoral tunnel and pulled out of the tibial tunnel. The No. 2 flipping suture and No. 5 passing suture are passed through the loop of the No. 5 suture and pulled out the lateral thigh. Under arthroscopic visualization, the EndoButton and the attached hamstring tendon graft are passed across the joint and into the femoral socket by use of the No. 5 passing suture. The DGST graft must be advanced until the previously placed insertion mark is seen to pass up into the femoral socket a distance of a few millimeters. This extra distance allows the EndoButton to pass outside the lateral femoral cortex and to flip. The No. 2 flipping suture is pulled in a proximal direction, parallel to the femoral tunnel, and the EndoButton will be felt to flip against the lateral femoral cortex. Correct deployment can be verified by pulling on the No. 2 sutures and feeling the EndoButton “teeter-totter” against the lateral femoral cortex. If any doubts exist about secure deployment of the EndoButton, fluoroscopy can be used to check the position of the EndoButton.

Tension is applied to the hamstring tendon graft, and the previously placed mark at the insertion length will be seen to slide back down the femoral tunnel. If the measurements are correct, this mark should lie at the entrance of the femoral tunnel. If it should become necessary to remove the graft, the No. 5 passing suture on the EndoButton can be pulled proximally, tipping the EndoButton away from the femoral cortex. The No. 5 safety suture that exited the tibial tunnel is pulled, tipping the opposite end of the EndoButton into the 4.5-mm tunnel. The EndoButton will then disengage from the femoral cortex, and the graft can be removed by applying tension to the whipstitches on the tibial end of the graft.

### 9. Graft Tensioning

The opposite ends of the hamstring tendon graft are applied to a graft-tensioning device (Smith & Nephew Endoscopy), and a preload of 80 to 100 N is applied to the graft. The tensioning device is designed to apply equal tension to each end of the four-stranded hamstring tendon graft and to spread the tendons apart, allowing easier insertion of the IntraFix tibial fastener. Application of equal tension to all four limbs of the hamstring tendon graft optimizes initial fixation strength and stiffness.<sup>16</sup> The knee is cycled from 0 to 90 degrees for a minimum of 30 cycles, with a preload of 80 to 100 N applied to the graft by the tensioning device. Application of a preload and cycling of the knee are important steps as they allow the EndoButton CL to settle on the femoral cortex and remove creep from the polyester continuous loop, the tendon whipstitches, and the hamstring graft. At present, the optimal graft tension and knee flexion angle during tibial fixation are unknown. Depending on the graft excursion pattern detected in cycling of the knee, we tend to fix the graft with the knee positioned between 0 and 20 degrees of flexion. The usual graft excursion pattern detected with our bone tunnel placements results in pulling of the DGST graft into the tibial tunnel (tightening) during the last 20 degrees of terminal extension. When there is minimal graft excursion detected, we tend to fix the graft with the knee at 20 degrees of flexion and near full extension with greater excursions. Because of the high fixation strength and stiffness and the resistance to slippage of the IntraFix tibial fastener, we caution against applying excessive tension (>80 N) to the graft or fixing the knee at a flexion angle of more than 20 degrees. A high graft tension force in combination with the knee flexed more than 20 degrees may result in a permanent flexion contracture.

### 10. Tibial Fixation

Although the IntraFix tibial fastener is available as a bioabsorbable implant, we continue to prefer the original Delrin plastic version. The bioabsorbable version requires more precise sizing and a larger number of implants, increasing inventory. In addition, the bioabsorbable screw can break, leaving the surgeon with a difficult salvage situation.

Concentric placement of the IntraFix tibial fastener is critical to the success of the technique and starts with the identification of the central axis of the tibial tunnel. The central axis of the tibial tunnel is identified by passing a 1.1-mm guide wire up the center of the tensioning device and down the center of the four graft strands into the knee joint. Once the central axis of the tibial tunnel is identified, the tensioner should be held in this orientation during the subsequent steps to avoid divergent placement of the implant. The four-quadrant trial dilator is inserted down the center of the four hamstring tendon strands and oriented so that each graft strand sits in its own channel. While the desired tension is maintained on the hamstring graft, the four-quadrant trial dilator is tapped into the tibial tunnel for a distance of 30 to 35 mm. This step compresses and separates the four tendon strands and notches the bone tunnel wall to receive the 30-mm IntraFix sheath.

The 30-mm IntraFix sheath is placed on the sheath inserter with the derotational tab on the sheath oriented to match the tab on the sheath inserter. The knee is positioned at the chosen flexion angle, and a final tension of 60 to 80 N is applied to the DGST graft by use of the tensioning device. It is important to maintain the chosen flexion angle and desired graft tension during the subsequent steps. The IntraFix sheath is inserted between the four graft strands, making sure that each graft strand is positioned into a separate channel of the sheath with the derotational tab on the sheath oriented at the 3-o'clock or 9-o'clock position. Orientation of the derotational tab at these positions allows the IntraFix sheath to be inserted more deeply into the tibia, avoiding prominence. The IntraFix sheath is tapped into the bone until the derotational tab is inserted flush with the cortex (Fig. 62-17).

The sheath inserter is removed, and the 0.042-inch guide wire for the tapered screw is inserted through the center of the sheath until a loss of resistance is felt as the tip of the guide wire enters the knee joint.

An IntraFix tapered screw size of 1 mm larger than the tibial tunnel diameter is chosen. For example, we use a 7- to 9-mm tapered screw for an 8-mm tibial tunnel. Given the typical size of most DGST grafts, the 7- to 9-mm tapered screw is most commonly used. While tension is maintained on the DGST graft, the IntraFix tapered screw is inserted into the sheath until the superior aspect of the screw head is flush with or buried just below the tibial cortex (Fig. 62-18). The best bone quality is at or next to the tibial cortex, and overly deep insertion of the screw may decrease fixation strength.<sup>5</sup> Protruding or prominent areas of the polyethylene sheath are trimmed flush with the tibial cortex with a No. 15 blade and a small bone rongeur.

The fixation strength of any intratunnel tibial fixation device depends on the local bone mineral density.<sup>4,20,24</sup> If the surgeon thinks that there was inadequate torque during the insertion of the tapered screw or if the patient



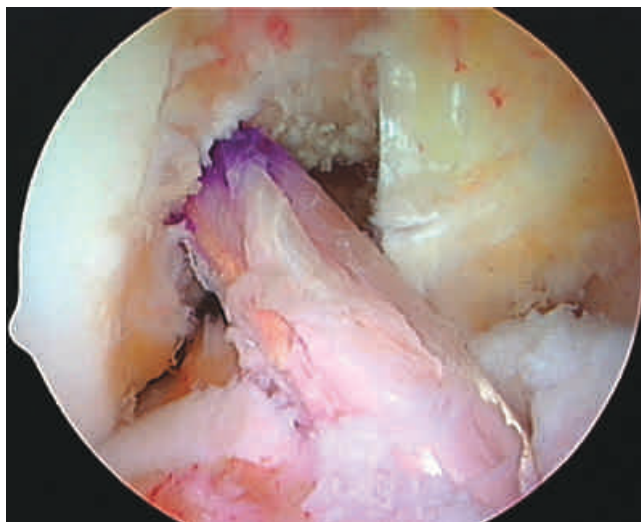
**Figure 62-17** Insertion of the 30-mm IntraFix sheath. The 30-mm IntraFix sheath is inserted down the center of the DGST graft, parallel to the axis of the tibial tunnel, with each tendon graft strand positioned in its own channel.



**Figure 62-18** Insertion of the IntraFix tapered screw. With the knee at the chosen flexion angle, tension is maintained on the graft strands by the graft-tensioning device, and the IntraFix tapered screw is inserted along the guide wire into the IntraFix sheath.

has soft bone, we recommend that supplemental tibial fixation be used. Depending on the length of the DGST graft, the protruding tendons can be stapled below the tibial tunnel with a small barbed staple (Smith & Nephew Orthopaedics, Memphis, Tenn), or the tendon whipstitches can be tied around an extra-small nonbarbed staple or tibial fixation post.





**Figure 62-19** Arthroscopic appearance of the DGST graft. The femoral attachment site of the graft is located along the side wall of the lateral femoral condyle, and the graft is oriented at a 10-o'clock position in the notch.

The stability and range of motion of the knee are checked. It is important to verify that the patient has full range of motion before leaving the operating room. The arthroscope is inserted into the knee, and graft tension and impingement are assessed. Our usual graft placement and tensioning technique result in the four strands of the DGST graft being maximally tight between 0 and 20 degrees, with the graft tension decreasing slightly as the knee is flexed to 90 degrees (Fig. 62-19). After confirmation that the patient has a full range of motion and negative Lachman and pivot shift test results, the passing and flipping sutures are pulled out of the lateral thigh.

### 11. Closure

A closed suction drain is inserted under the sartorius fascia up into the hamstring harvest site and is helpful in preventing postoperative hematoma formation and decreasing ecchymosis along the medial side of the knee. The sartorius fascia that was preserved during the graft harvest is repaired back to the tibia with a 0 absorbable suture. The subcutaneous tissue is closed in layers with fine absorbable sutures. A running 3-0 Prolene subcuticular pullout suture produces a cosmetic closure. A second solution of 5 mg of morphine sulfate plus 20 mL of 0.25% bupivacaine with 1:100,000 epinephrine is injected into the suprapatellar pouch, and a 30-mg bolus of ketorolac is given for postoperative pain control. The continuous intravenous ketorolac infusion is continued until the patient is discharged from the day-surgery unit. A light dressing is applied over the wound, followed by a thigh-length TED antiembolism stocking, Cryo/Cuff (DJ Orthopedics, Vista, Calif), and knee immobilizer. The Hemovac drain is



A

**Figure 62-20** Postoperative radiographs. **A**, Proper tibial tunnel placement results in placement of the EndoButton at the flare of the distal femur. A small staple was used for supplemental tibial fixation in this case.

removed when the patient is discharged from the day-surgery unit.

## Postoperative Management

### Follow-up

The patient is seen at 7 to 10 days for suture removal and postoperative radiographs (Fig. 62-20).

### Rehabilitation

Our postoperative rehabilitation protocol is described in Table 62-1. The weight-bearing schedule is modified if a



B

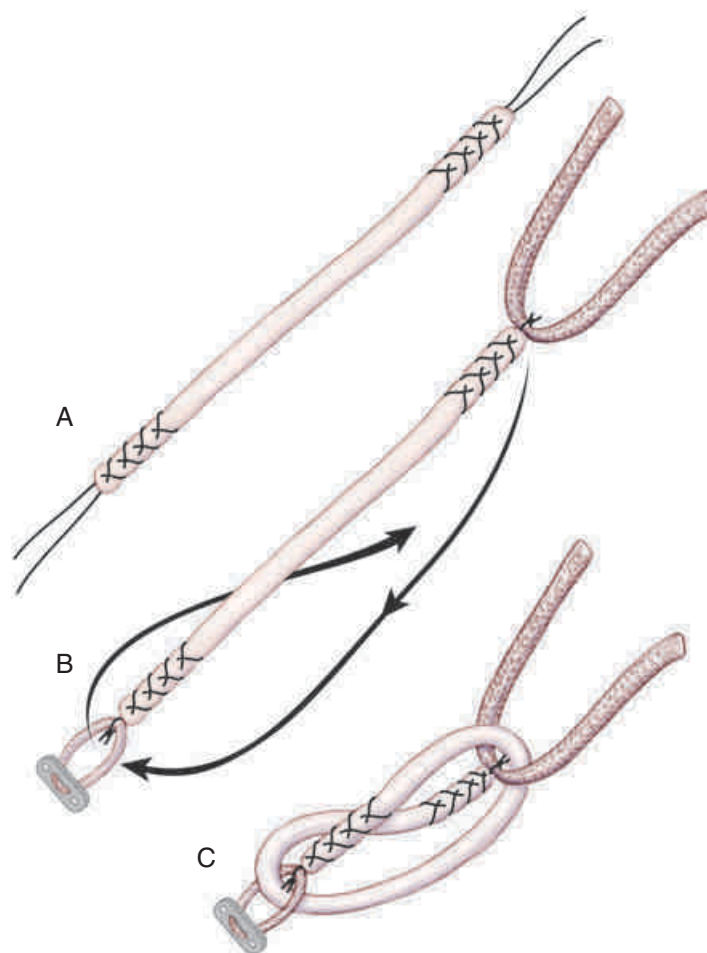
**Figure 62-20, cont'd B**, Lateral radiograph in maximum hyperextension. The tibial tunnel is parallel and posterior to Blumensaat's line.

meniscus repair, microfracture, or other associated ligamentous surgery has been performed.

## Complications

The risks of complications such as infection, deep venous thrombosis, and loss of motion are the same as for ACL reconstructions performed with other graft sources. However, we are unaware of reports of extensor mechanism rupture or patellar fracture after ACL reconstruction performed with hamstring tendon grafts. Complications unique to hamstring tendon grafts include premature amputation of the hamstring tendons, saphenous nerve injury, bleeding at the hamstring tendon harvest site, and hamstring muscle "pulls."

The risk of premature amputation of the tendons can be minimized by following the recommendations outlined in the section on graft harvest. If the gracilis tendon is amputated but the semitendinosus is successfully harvested, it is possible in most cases either to triple or to quadruple the semitendinosus tendon, depending on its length (Fig. 62-21). In these situations, the EndoButton CL can still be used for femoral fixation; however, because of the shorter length of the graft construct, alternative tibial fixation is obtained by tying the EndoButton tape



D

**Figure 62-21** Technique for preparation of a triple-stranded semitendinosus graft. **A**, Semitendinosus graft with No. 2 nonabsorbable whipstitches placed at each end. **B**, The appropriate-length EndoButton CL is tied to one end of the semitendinosus graft, and the other end of the semitendinosus tendon is tied to EndoButton tape (Smith & Nephew Endoscopy). **C**, The end of the semitendinosus graft with the EndoButton tape is looped through the EndoButton CL and the EndoButton tape is passed through the resulting loop of semitendinosus graft, making a three-stranded semitendinosus graft. **D**, Final appearance of a triple-stranded semitendinosus graft. (From Brown CH, Sklar JH, Darwich N. Endoscopic anterior cruciate ligament reconstruction using autogenous doubled gracilis and semitendinosus tendons. *Tech Knee Surg* 2004;3:233.)

around a fixation post or an extra-small nonbarbed staple. If necessary, the tibial fixation can be augmented with a 25- to 30-mm bioabsorbable screw with a diameter 1 mm greater than that of the tibial tunnel. If the semitendinosus tendon is amputated, it will be necessary to use an alternative autograft, such as the patellar tendon or

**Table 62-1** Postoperative Rehabilitation Protocol for Hamstring ACL Reconstruction

Goals	Exercises
<b>Phase I: Days 0-7</b>	
Control pain, inflammation, joint effusion, swelling	Knee Cryo/Cuff, thigh-length TED stocking, elevation
Full passive extension equal to that of the opposite knee	Heel props, pull knee into hyperextension with elastic band
Achieve 90-degree flexion	Wall slides, gravity-assisted flexion sitting on the edge of a table
Prevent quadriceps shutdown	Electrical muscle stimulation, quad isometrics, straight-leg raises, active assisted extension 90-0 degrees
Prevent heel cord contracture	Ankle pumps, calf stretches with elastic bands
Gait training	Weight bearing as tolerated with knee immobilizer and crutches; meniscus repair, revisions: $\uparrow$ 25% body weight/week, wean off crutches at end of week 4
<b>Phase II: Weeks 1-2</b>	
Control inflammation, pain, joint effusion, swelling	Continue phase I exercises
Maintain full symmetric extension	Continue phase I exercises
Achieve 100-125 degrees of flexion	Assisted flexion with use of opposite leg, wall slides, heel drags, rolling stool
Develop muscle control to be safely weaned off knee immobilizer and crutches	Continue phase I exercises, mini-squats, toe raises, active extension 90-30 degrees
Protect hamstring donor site	Prevent sudden, forceful hamstring stretching with the knee and hip in extension, such as attempting to lean forward to put on socks and shoes or leaning forward to pick up an object off the floor
<b>Phase III: Weeks 2-4</b>	
Maintain symmetric extension	Heel props, prone heel hangs, lock knee out, "stand at attention" Patients who fail to obtain symmetric extension should be considered for extension splinting or a "drop-out" cast
Wean off knee immobilizer	Discard immobilizer when straight-leg raises are performed without a quad lag
Wean off crutches	One crutch with ability to bear 75% of body weight; discard crutches with full weight bearing and ability to walk with normal heel-toe gait
Achieve 125-135 degrees of flexion	Heel slides, sitting back on heels
Hamstring strengthening	Hamstring isometrics 0-90 degrees, pull rolling stool backward
Quadriceps strengthening	Continue phase II exercises, mini-squats with elastic band for resistance
Hip strengthening	Side-lying hip abduction, adjustable-angle hip machine
Proprioceptive training	Balance board double-leg stance
Aerobic conditioning	Elliptical machine
<b>Phase IV: Weeks 4-6</b>	
Obtain full flexion	Heel slides, sitting back on heels
Continue quadriceps, hamstring, and hip strengthening	Mini-squats, leg press 50-0 degrees, front step-ups (control hip valgus), StairMaster backward, proprioceptive neuromuscular facilitation, toe raises, seated leg-curl machine 0-90 degrees
Proprioceptive training	Balance board double- and single-leg stance, add ball throws and catches
Aerobic conditioning	Stationary bike (adjust to protect patellofemoral joint), elliptical machine, pool exercises

Continued on overleaf.

**Table 62-1** Postoperative Rehabilitation Protocol for Hamstring ACL Reconstruction—cont'd

Goals	Exercises
<b>Phase V: Weeks 6-12</b>	
Increase lower extremity strength and endurance	Increase intensity of phase IV exercises, high-speed (300-360 degrees/sec) isokinetics, extension (90-30 degrees), flexion (0-90 degrees), elliptical machine, StairMaster backward and forward, treadmill walking, pool exercises
Advance proprioceptive and perturbation training	Increase intensity of phase IV exercises
<b>Phase VI: Weeks 12-16</b>	
Increase quad and hamstring strength	Increase intensity of phase IV exercises, midrange (180-240 degrees/sec) isokinetics, extension (90-30 degrees), flexion (0-90 degrees)
Increase hamstring strength at high flexion angles	Prone leg curls with elastic tubing and leg-curl machine (90-120 degrees)
Jogging and running	Treadmill jogging and running, outdoor running on low-impact surface
Crossover drills	Lateral step-over, carioca drills
<b>Phase VI: Weeks 16-24</b>	
Hard cutting and sports-specific drills	Figure-of-eight, circle run, plyometrics, hopping, jumping, sprinting
Return to noncontact sports at 4-5 months	Golf, tennis, biking, hiking
Return to full sports at 6 months (revisions, 9 months)	

quadriceps tendon, or allograft tissue if preoperative consent has been obtained. The possibility of premature amputation of the tendons should be discussed during the

informed consent process, and the patient and surgeon should agree on a course of action should this complication occur.

#### PEARLS AND PITFALLS

- Before detaching the conjoined tibial insertion of the two tendons and their dissection off the tibia, it is important to clearly identify and to bluntly separate the tendons from the underlying MCL. Failure to do so may result in the mistaken dissection of the MCL off the tibia.
- Leaving the distal 5 mm of each tendon attached to the fascial flap makes reattachment of the flap easier at the end of the procedure.
- Apply firm traction to the tendon whipstitches to release any of the remaining fascial connections before harvest of the tendon grafts.
- Complete release of the fascial connections to the medial head of the gastrocnemius can be verified by the absence of tethering of the muscle and bowing of the tendon when traction is applied to the whipstitch.
- Drilling the femoral tunnel first minimizes fluid extravasation, maintains joint distention to improve visualization, and minimizes use of the tourniquet.
- Use fluoroscopy to confirm the femoral tunnel starting point.
- Make adjustments to the femoral tunnel starting position by viewing through the anteromedial portal.
- The knee must be flexed 120 degrees or more when the anteromedial portal technique is used.
- The femoral tunnel length can be increased by drilling the femoral guide pin into the lateral femoral condyle a distance of 2 to 3 mm, then angulating the femoral offset aimer toward the midline of the knee.
- Increasing the infusion pump pressure when the knee is fully flexed can improve visualization in the notch.
- Visualization can be improved during drilling of the femoral tunnel by suctioning debris out of the joint with use of a shaver placed through the anteromedial portal.

## Results

Historical perceptions of hamstring ACL reconstructions are that they produce unpredictable objective stability, tend to stretch out with time, and are not as good as reconstruction with a patellar tendon graft.

Meta-analyses of Yunes et al<sup>33</sup> and Freedman et al<sup>14</sup> concluded that patellar tendon autografts produce greater

stability and result in higher postoperative activity levels. However, these studies included some series in which older hamstring fixation methods and two-stranded hamstring tendon grafts were used. Prospective randomized controlled studies comparing quadrupled hamstrings with bone-patellar tendon-bone reconstructions have demonstrated no significant differences in laxity or in clinical outcome measures at early follow-up.<sup>1,2,13,15,22,26,30</sup> A meta-analysis

performed by Prodromos et al,<sup>28</sup> in which the results were stratified by graft and fixation type, demonstrated that four-stranded hamstring tendon grafts had overall stability rates equal to or higher than those of patellar tendon grafts. This study also demonstrated that the four-stranded hamstring stability rates were fixation dependent; series using Endo-Button femoral fixation and second-generation tibial fixa-

tion resulted in higher stability rates than did all other graft-fixation combinations. When the literature is carefully analyzed, four-stranded hamstring ACL reconstruction with second-generation fixation is comparable to patellar tendon autograft reconstruction, and current preconceptions regarding four-stranded hamstring ACL reconstructions may be a historical artifact (Table 62-2).

**Table 62-2** Outcomes for Four-Stranded Hamstring ACL Reconstructions

Author	Year	Average Follow-up	Manual Max KT $\leq 2$ mm	Clinical Outcome	Donor Site Morbidity
<b>EndoButton Femoral Fixation with Second-Generation Tibial Fixation</b>					
Cooley et al <sup>11</sup>	2001	5.7 years	100%	85% IKDC score normal or nearly normal	24% increased PF crepitus
Eriksson et al <sup>12</sup> Prospective randomized STG vs. PT	2001	33 months	STG, 43% PT, 48% NS	Lysholm score increased from 61 to 86 58% IKDC score normal or nearly normal Lysholm and Tegner scores, range of motion, laxity NS from PT	STG and PT PF pain scores NS Kneeling pain: PT > STG
Feller and Webster <sup>13</sup> Prospective randomized STG vs. PT	2003	3 years	85%	93% IKDC score normal or nearly normal PT greater extension deficit; quad strength, activity levels NS from PT	Kneeling pain: STG, 26%; PT, 67%
Gobbi et al <sup>15</sup>	2003	3 years	90%	Lysholm score, 91 72% IKDC score normal or nearly normal	Kneeling pain, 7% 10% mild PF crepitus
Gobbi ST vs. STG	2005	3 years	ST, 88% STG, 89%	Lysholm score: ST, 92; STG, 94 94% IKDC score normal or nearly normal 8% required hardware removal	Kneeling pain, 3% 10% mild PF crepitus
Prodromos et al <sup>27</sup>	2005	4.5 years	86%	Lysholm score, 95 72% IKDC normal or nearly normal No difference between males and females in Lysholm score or KT laxity scores No patient required hardware removal	PF crepitus: mild, 20%; moderate, 3%
<b>Cross-Pin Femoral Fixation</b>					
Aglietti et al <sup>1</sup> Prospective randomized STG vs. PT	2004	2 years	STG, 57% PT, 65% NS	IKDC score normal: STG, 57%; PT, 63% (NS) Range of motion, quad and hamstring strength, postoperative activity levels NS	PF symptoms: NS Kneeling pain: STG, 15%; PT, 62%
Harilainen et al <sup>17</sup> Prospective randomized STG vs. PT	2005	2 years	STG, 72% PT, 62% NS	88% negative pivot shift Lysholm score, 96 85% IKDC score normal or nearly normal Knee scores, range of motion, quad and hamstring strength NS STG: 58% required removal of tibial fixation hardware	Not reported
Fabbriciani	2005	2 years	61%	90% IKDC score normal or nearly normal	Not reported

IKDC, International Knee Documentation Committee; PF, patellofemoral; PT, patellar tendon; NS, not significant; ST, semitendinosus tendon; STG, semitendinosus tendon and gracilis construct.

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