Mini-incision Patellar Tendon Harvest and Anterior Cruciate Ligament Reconstruction Using Critical Bony Landmarks

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Abstract: Graft choice remains an area of contention in anterior cruciate ligament reconstruction. Poorer cosmetic results and anterior knee pain remain a problem in the use of autologous patellar tendon grafts despite excellent clinical results when compared with autologous hamstring tendon grafts. Using a 2-incision technique to harvest the patellar tendon grafts has been shown to decrease the risk of anterior knee pain to a level comparable to hamstring tendon grafts. Proper graft tunnel placement and orientation also remain controversial with several recent researchers arguing the ability to perform an anatomic reconstruction using a conventional endoscopic transtibial technique. We will describe a relatively simple and cosmetically acceptable 2-incision technique for harvesting a bone-tendon-bone graft. In addition, we will describe the bony landmarks that should be used to ensure proper anatomic graft placement and the appropriate angles that need to be used for the tibial tunnel to drill the femoral tunnel in an anatomic position and carry out a successful endoscopic transtibial tunnel anterior cruciate ligament reconstruction.

Key Words: anatomic ACL reconstruction, patella bone tendon bone, Residence Ridge, intertubercle ridge

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The arthroscopic anterior cruciate ligament (ACL) reconstruction saw its early development in the mid-1980s with generalized acceptance and fruition in the 1990s as a universal approach to ACL reconstruction. Although initially developed to decrease morbidity over the open procedures of the day, graft harvest morbidity remains a potential problem. Among the available autograft sources, the patellar tendon, hamstring tendon, and quadriceps tendon have their proponents for and against their utilization. Anterior knee pain and kneeling pain have been cited as significant sources of postoperative donor-site problems after patellar tendon harvest despite superior static knee stability, lower rate of graft failure, and increased patient satisfaction when compared with autologous hamstring tendon grafts (HSTGs).[1] Kartus et al[2] have argued that injury to the infrapatellar branch of the saphenous nerve is a major cause of morbidity. They have also showed both in clinical and cadaveric studies a method for minimizing patellar tendon graft site morbidity by protecting the infrapatellar branch of the saphenous nerve using 2 small incisions rather than a larger one to harvest the graft.[3,4] Liden et al[5] also show similar results stating that a 2-incision technique to harvest the patellar tendon grafts was shown to decrease the risk of anterior knee pain to a level comparable to HSTGs. We first presented an arthroscopic patellar tendon ACL reconstruction at the ESSKA meeting in 1986 and at the AAOS meeting in 1987 in which the method of patellar tendon harvest was similarly applied.[6,7] Our experience since then has been similar to the one reported by Kartus on the benefits of this technique.[3,4]

We later realized that the greatest benefit to the patient of an arthroscopic technique was the improved accuracy that an arthroscopic technique afforded in reconstructing the ACL in a more anatomic position. Although anatomic reconstruction has been recently emphasized, the exact location of graft placement and the method of tunnel drilling remain controversial. Various methods have been advocated to determine tunnel placement based on guides, measurements from the other anatomic structures, and the face of a clock. Some of these methods have considerable variation in their description among authors, such as the o'clock position that has been described with the center of the clock placed at different levels within the femoral notch.[8–11] Computer-assisted navigation and robotics have significant potential to aid the surgeon in determining optimal position, although high cost and limited availability decrease its use.[12] Arguments also exist concerning the ability to drill the femoral tunnel in an anatomic location if performed through tibial tunnel, arthroscopic portal, or lateral approach.[13,14]

We recently published a computed tomography (CT)-based anatomic study correlating ACL anatomy with bony landmarks on the tibia and femur that are easily identifiable through standard arthroscopic approach.[15] We believe that a surgeon should identify these landmarks and orient the reconstruction within these boundaries. In our opinion, reproduction of the anatomic position of the ACL graft is the most important determinant to successful ACL reconstruction. The type of graft and the graft fixation techniques are important, but they are of lesser importance than the accurate placement that an arthroscopic visualization affords.

We will describe a relatively simple, cosmetically acceptable, and reproducible technique for harvesting a bone-tendon-bone (BTB) graft using a 2-incision technique. In addition, we will describe the bony landmarks that, we believe, should be used to ensure correct anatomic placement and the appropriate angles that need to be used for drilling of the tibial tunnel to place the femoral tunnel in an anatomic position and to perform a successful endoscopic transtibial tunnel ACL reconstruction.

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SURGICAL TECHNIQUE

If preoperative workup and examination under anesthesia establishes an ACL deficiency, we proceed directly to harvesting the BTB graft. If the diagnosis is still questionable, we perform an arthroscopy first and then proceed to graft harvest once the diagnosis has been established. It is typically easier to harvest the BTB graft before any swelling induced by the arthroscopic fluid.

Patellar Tendon Graft Harvest

The patellar tendon BTB graft is harvested through 2 longitudinal incisions (Fig. 1). The only areas that should be visualized are the bony harvest sites; therefore, the incisions are made directly over the bony harvest sites. Typically, the smaller and farther apart the incisions are, the more cosmetically pleasing the incisions are to the patient. The tendon harvest can be performed subcutaneously using a meniscotome or Smillie knife (Fig. 2). A uniform tensile load is applied to the tendon by placing the knee at 60 to 90 degrees during the graft harvest. The first incision is made just medial and distal to the patellar insertion (Fig. 3). As this incision is intended to be used for the tibial tunnel and the graft harvest, the incision is made medial to the tibial tubercle. A 2-cm incision is typically adequate. Subcutaneous dissection should be performed bluntly to avoid injury to the infrapatellar branch of the saphenous nerve. The skin can be easily retracted laterally to expose the tendon insertion on the tibial tubercle. The medial and lateral edges of the tendon should be visible through this incision. We use a caliper or ruler to measure the tendon size and the graft size (Fig. 4).

The patellar tendon is incised using a no. 15 blade approximately 7 to 8 mm lateral to the medial border of the tendon (Fig. 3). The tendon incision should be intrafascicular and carried proximally only a short distance, but it should be extended distally over the entire BTB insertion for a distance of approximately 2 to 3 cm, until the termination of the tendon at the anterior tibial crest is identified. There is typically a distinct change in the tissue characteristics from the tendon insertion to the periosteum over the proximal tibia; this change can easily be palpated and visualized. Graft's width is typically 8 to 10 mm, depending on the patient's size, and can be measured using calipers or a ruler (Fig. 4). An incision is then made at the lateral edge of the graft and again carried proximally for a short distance, but is extended distally until the termination of the tendon insertion on the tibia (Fig. 3). A straight meniscotome or Smillie knife is then used to cut the tendon proximally, deep to the paratenon (Fig. 2). As the strong, longitudinally oriented collagen fibrils are held together by the loose connective tissue of the endotenon, the meniscotome creates a very clean division of the collagen fibrils without cutting across the tendon.[16] This step should only be taken before the bone graft harvest, when all fibers are under equal tension, to avoid cutting across the tendon harvest. If this step is forgotten, it is better to separate the graft from the tendon later by simply pulling the graft from the tendon during graft passage to the proximal incision. The efficacy of this procedure for cutting the graft safely can be shown by performing it in a patient through a standard open fashion before applying it in a patient with the 2-incision technique.

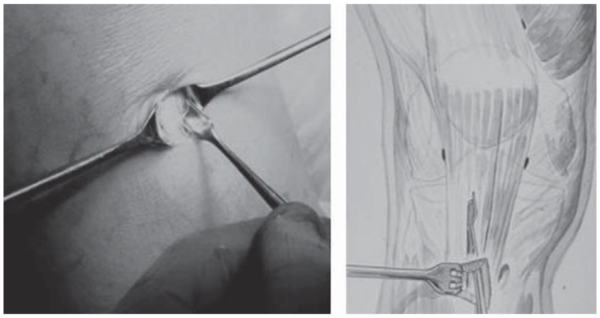

FIGURE 2. Patellar tendon incisions using a meniscotome or Smillie knife.

Bone Block Harvest

The depth of the distal insertion of the tendon can be illustrated to a surgeon by placing the handle of an Adson forceps into the defect proximal to the tibial tubercle and

FIGURE 1. Two longitudinal incisions used for patellar tendon graft harvest.

FIGURE 3. Incision of the patellar tendon insertion using a no. 15 blade.

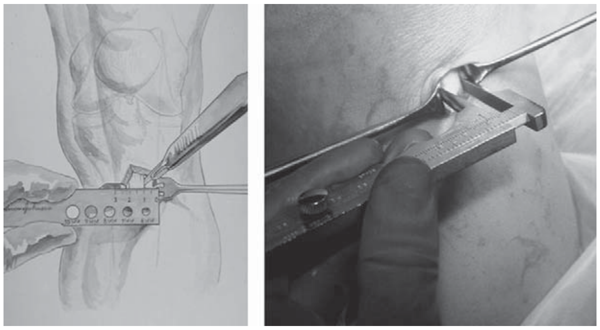

FIGURE 4. Use a caliper or ruler to measure the tendon size and graft.

then turning the handle sideways. The bone block can then be harvested with a microoscillating saw (Fig. 5). Longitudinal cuts are made first in the tubercle in line with the tendon insertion. The saw cuts are carried distally until the termination of the patellar tendon insertion. This can be identified by the change in resistance to the saw cut as the saw cut is carried distally into the denser bone of the proximal tibial crest. Once this change in bone density is observed, a transverse cut can be made with the saw, linking the 2 longitudinal saw cuts. The bone block can be elevated into the wound by prying the graft distally with a curved 0.25-inch osteotome and mallet (Fig. 6). The bone block can be held with a Kocher clamp, taking care to place the arms of the clamp only on the medial and lateral edges of the bone block, thereby avoiding damage to the tendon insertion. The bone block can be trimmed to the appropriate diameter and then drilled with a 0.062 K-wire. By drilling from the cancellous to the cortical surface and utilizing the smooth K-wire, damage to the tendon can be minimized. A heavy suture is then placed in the most proximal (closest to the tendon insertion) drill hole. This allows the graft to bend upon itself when pulling proximally, and minimizes the tissue hang-up when pulling the graft from the distal to the proximal wound.

To identify the graft origins on the patella, the graft is pulled on distally with the suture and the site of tension is palpated on the distal pole of the patella (Fig. 7). This identifies the site for the proximal incision. The proximal incision is placed only over bone on the distal pole of the patella in line with the distal incision (Fig. 8). A 2-cm incision is then created directly over bone, carried bluntly to the patella until the longitudinal fibers of the patella tendon origin are identified. The fascia, overlying the patella, are freed subcutaneously both proximally and distally for a short distance to facilitate graft passage.

FIGURE 5. Bone block cuts using a micro-oscillating saw.

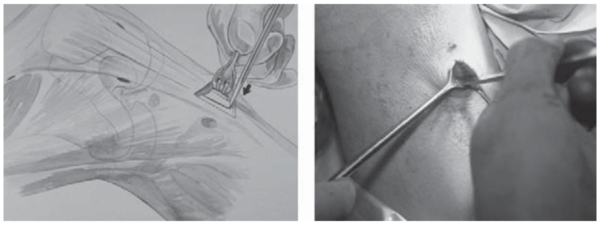

FIGURE 6. Bone block elevated using an osteotome and mallet.

A Kelly clamp is then placed from the proximal incision to the distal incision subcutaneously by placing it posterior to the paratenon and anterior to the patellar tendon (Fig. 9). The suture, earlier applied to the tendon, is then pulled with the clamp from distal to proximal (Fig. 10). The tendon is allowed to fold on the bone block and is pulled into the proximal incision.

Tension is then applied to the tendon distally to identify the origin of the tendon on the distal pole of the patella (Fig. 11). The longitudinal fibers of the graft and the remaining intact tendon are identified and split by pushing the tip of Metzenbaum scissors from distal to proximal (Fig. 11). As I am right handed, I usually make the right-sided saw cut first on either the right or left knee, then I proceed to the transverse cut (Fig. 12). The last cut would be on the left side and be identified by, again, blunt dissection from distal to proximal, therefore extending the dissection on the origin of the patellar tendon to the left side of the proximal transverse cut. Care must be taken when creating the saw cuts to ensure that they are made deep enough and meet completely at their corners but do not extend into the remaining patella to prevent patellar

FIGURE 7. Pulling the graft to identify the patellar tendon origin.

FIGURE 8. Proximal incision over the distal pole of the patella.

fracture. The bone block can be carefully harvested by prying the proximal edge of the bone block with a 0.25-inch osteotome and mallet. Excessive force should be avoided when prying on the patellar bone block to prevent fracture. If more force is necessary to harvest the bone block, the saw cuts are rechecked, deepened, and extended as necessary to ensure that they are adequate so that no excessive force is applied. The bone block is then trimmed, drilled, and threaded with heavy sutures. As the patellar origin of the patellar tendon tends to be broader than the tibial insertion, the patellar bone block typically has a larger diameter than the tibial bone block. I will therefore normally use the tibial bone block in the femoral hole and the patellar bone block in the tibia. Graft passage from smaller to larger is therefore much easier, and the femoral tunnel can be a smaller diameter than the tibial tunnel.

ARTHROSCOPIC SURGICAL PROCEDURE

The proximal incision is used over the patellar tendon defect when placing the arthroscope. It is perfectly placed for visualizing the notch and the medial and lateral compartments. The medial arthroscopy portal is used for instrumentation and is made just medial to the patellar tendon. The incision is typically oriented so as to facilitate the passage of the instrumentation into the notch rather than into the medial compartment.

After addressing any other intra-articular pathology, the notch is debrided. A notch-plasty is usually not necessary for visualization unless large osteophytes are present. The lateral wall is debrided of soft tissue to identify the bony borders of the ACL. The tibial ACL stump is left intact to act as a trap door for the prevention of fluid extravasations after tibial tunnel drilling. The bony borders of the ACL insertion on the tibia are usually easily visualized with an intact ACL and excision is not necessary.

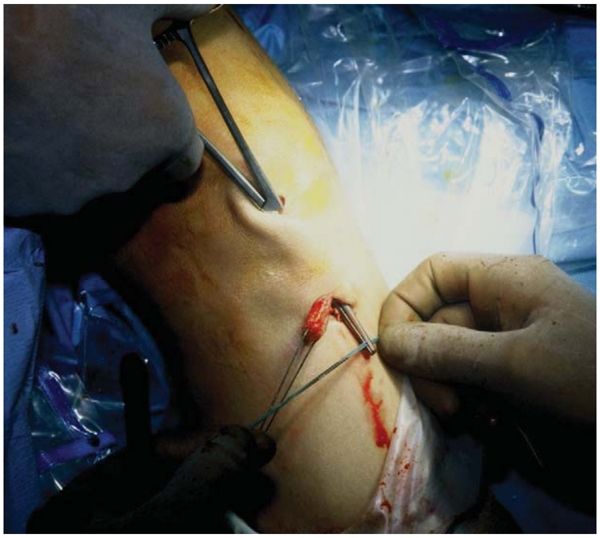

FIGURE 9. The Kelly clamp is placed posterior to the paratenon from the proximal to the distal incision for graft passage.

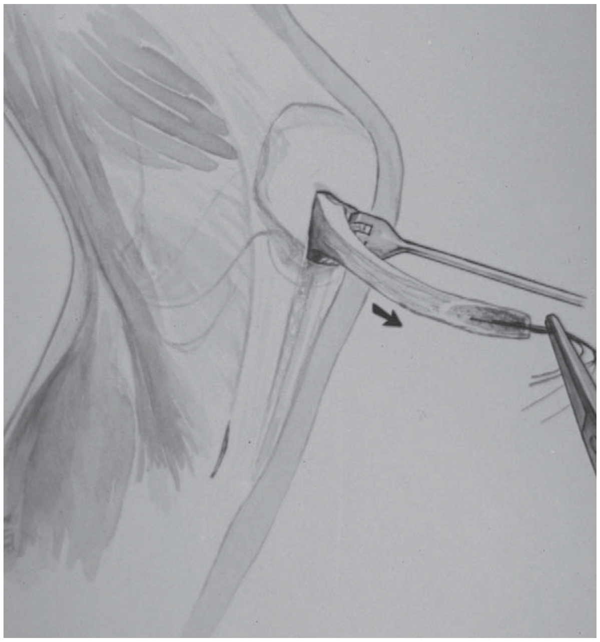

FIGURE 10. Patellar tendon graft transferred to the proximal incision.

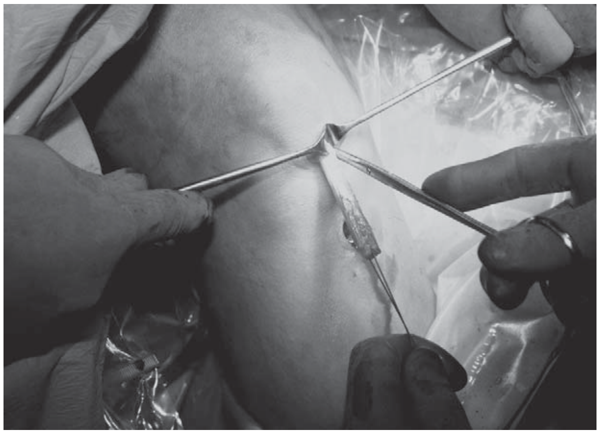

FIGURE 11. Tension on the patella is applied to identify origin on the distal pole of the patella. Metzenbaum scissors spreading the longitudinal fibers of the patellar origin from distal to proximal.

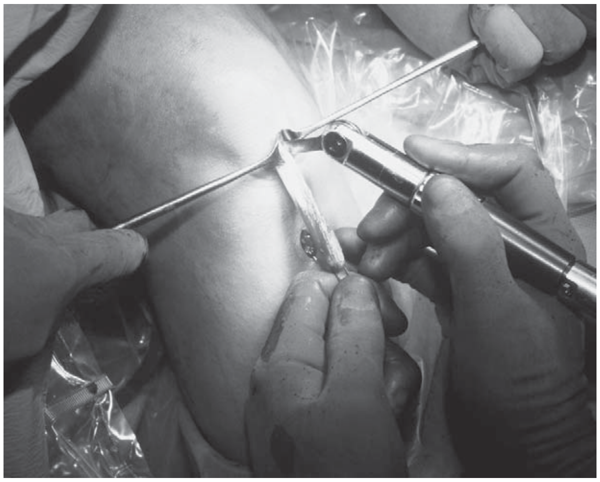

FIGURE 12. Proximal saw cut.

We have identified the following anatomic bony borders of the ACL.[15] With the knee at 90 degrees of flexion and from the anterior arthroscopy perspective, the anterior border of the ACL is a prominence or ridge on the lateral wall of the notch, commonly known as Residence Ridge or Femoral ACL Ridge (Figs. 13, 14). This can typically be visualized and palpated as a change in the slope angle of the lateral wall of the intercondylar notch. This prominence can be thought of as a tubercle that acts to move the origin of the ACL medially from the lateral wall of the notch, thereby preventing abrasion. The superior border is the connection of the lateral wall to the roof of the notch (Figs. 13, 14). The posterior and inferior borders are within 3 mm of the articular surface of the lateral femoral condyle (Figs. 13, 14). All of these bony landmarks can be easily visualized and palpated through the central transpatellar portal. I used the arthroscopic awls to mark a spot in the center of these borders so that the anterior edge of the tunnel would be posterior to the Residence Ridge, up to but not onto the roof of the notch, and within a few millimeters of the articular surface posteriorly and inferiorly. I always identify the borders in the same position of approximately 85 to 90 degrees of flexion to be consistent in orientation from patient to patient. Orientation can also be checked by moving the arthroscope from posterior to anterior to visualize the articular surface of the tibial plateau.

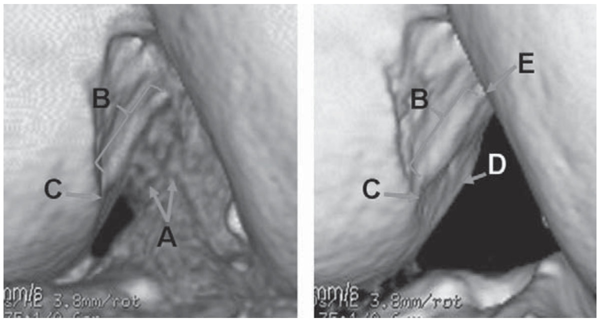

FIGURE 13. Simulated arthroscopic view of the femoral intercondylar notch with and without soft tissue. Residence Ridge or Femoral arthroscopic anterior cruciate ligament (ACL) Ridge is the anterior border for the ACL fibers at the femoral insertion site. A, ACL, (B) Residence Ridge, (C) inferior border, 3.5 mm from the articular surface, (D) posterior border, 3 mm to articular surface, (E) superior border is the junction of the lateral wall and the roof of the intercondylar notch. With permission from *AJSM*. 2008;36:2083–2090.

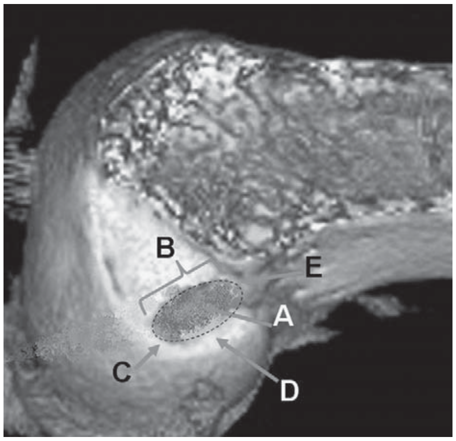

FIGURE 14. Sagittal view of the lateral wall of the intercondylar notch with an intact anterior cruciate ligament (ACL) footprint, (A) ACL, (B) Residence Ridge, (C) inferior border, 3.5 mm from the articular surface, (D) posterior border, 3 mm to articular surface, (E) superior border is the junction of the lateral wall and the roof of the intercondylar notch. The dotted line is the approximate footprint of the ACL origin on the femur.

Attention can then be directed to the tibia. Our CT study showed 2 consistent bony landmarks as ACL borders.[15] The medial intercondylar ridge of the tibia acts as the medial border, an extension of the medial intercondylar tubercle of the tibial spine (Fig. 15). The anterior intertubercle ridge of the tibial spine acts as the posterior border, the ridge between the medial and lateral intercondylar tubercles (Fig. 15). This ridge is easily seen on the lateral side by displacing the ACL medially with a probe. It can also be palpated from either the medial or lateral side of the ACL with a probe.

The guide pin should be placed so that the posterior margin of the tibial tunnel is just anterior to the intertubercle ridge after over drilling with the appropriately sized reamer. Placement of the tibial tunnel posterior to this ridge risks creating a central cruciate, whereas too anterior placement would risk impingement. The medial border should be just medial to the medial intercondylar ridge. Using a tibial drill guide, a guide pin is drilled from medial to the tibial tubercle to the preselected position in the ACL tibial footprint.

Our CT scan study also showed optimal angles for tibial tunnel drilling. If the physician is using a transtibial technique for drilling the femoral tunnel, the tibial tunnel should be optimally orientated to successfully reach the anatomic origin on the femur. Guide pin placement should be determined in all the 3 planes: sagittal, coronal, and axial.

When the knee is at 85 to 90 degrees of flexion, the ACL is oriented approximately 40 to 45 degrees to the top of the tibial plateau in the sagittal plane (Fig. 16). Placing the guide pin at 40 degrees optimizes tunnel orientation to access the femoral ACL origin when the knee is at 90 degrees of flexion. This is slightly more than the 35.2 degrees (54.8 degrees from the longitudinal axis of the tibia) as recommended by Heming et al.[10] If the knee is flexed to

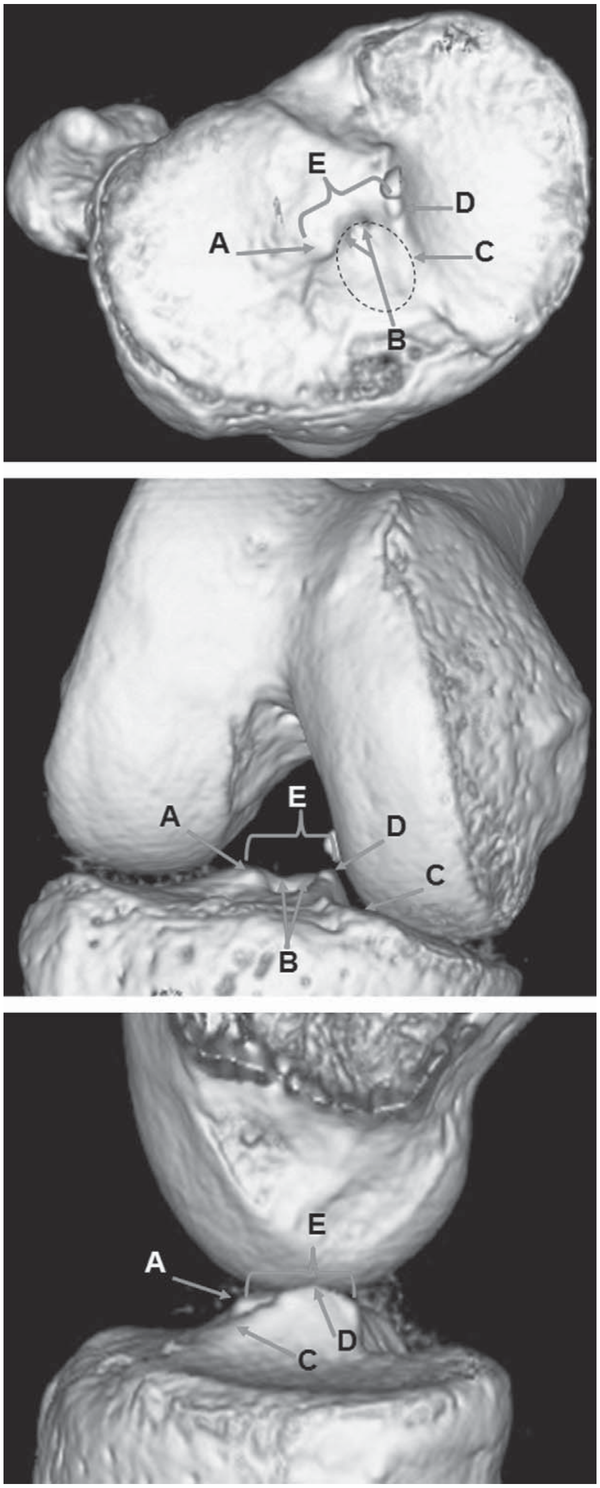

FIGURE 15. A, Lateral intercondylar tubercle, (B) anterior intertubercle ridge or tibial anterior cruciate ligament (ACL) ridge, (C) medial intercondylar ridge of the tibia, (D) medial intercondylar tubercle, and (E) intercondyloid eminence (tibial spine). The dotted line is the approximate footprint of the ACL insertion on the tibia. With permission from *AJSM*. 2008;36:2083–2090.

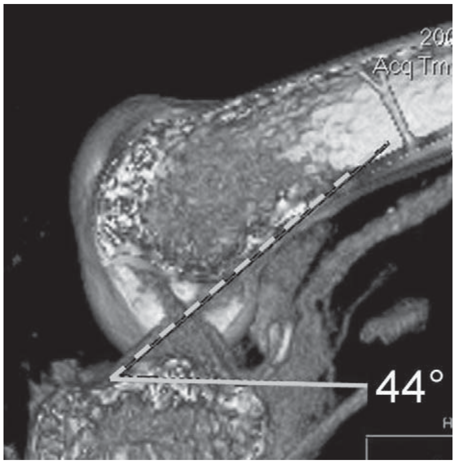

FIGURE 16. Sagittal view of the knee at 85 to 90 degrees. The anterior cruciate ligament is oriented at 40 to 45 degrees with respect to the tibial plateau.

more than 90 degrees, the tibial guide angle should be correspondingly lowered because the 4-bar link mechanism of the ACL and posterior cruciate ligament draws the ACL into a shallower angle with the tibial plateau.[17] Failure to drill a shallow enough angle would cause difficulty in placing the femoral guide pin posteriorly enough on the femoral tunnel. If the tibial tunnel is at too-steep an angle, the ACL graft may either be too anterior and superior in the notch, or it may result in an over drilling of the tibial tunnel when placing the femoral tunnel. This creates a more posterior tunnel on the tibia. Either of these positions could result in a central cruciate and failure to restore proper knee kinematics.

It should also be noted that a tunnel drilled at a 40-degree angle to the tibial surface will create an oblong opening rather than a round hole (Fig. 17). Whereas a guide pin placed parallel to this tibial surface with a 10-mm hole would result in a 10-mm opening of the tibia, a guide pin placed at approximately 40 degrees to the surface of a tibial tubercle would create an oblong tibial tunnel with over drilling by a 10-mm reamer. The drill hole in the tibia would be approximately 15.5 mm in its anterior-to-posterior diameter and, therefore, would have a radius of 7.75 mm in the sagittal plane. Equation (1) describes the relationship between the angle of the drill and the long axis diameter of

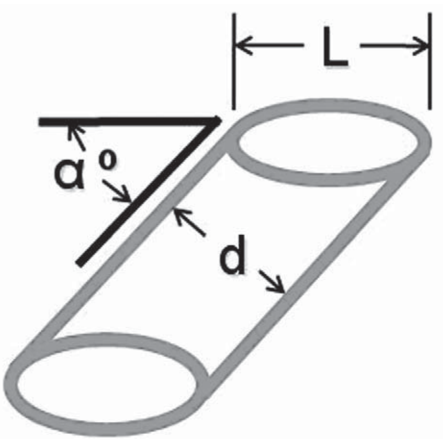

FIGURE 17. Drill angle and long axis relationship.

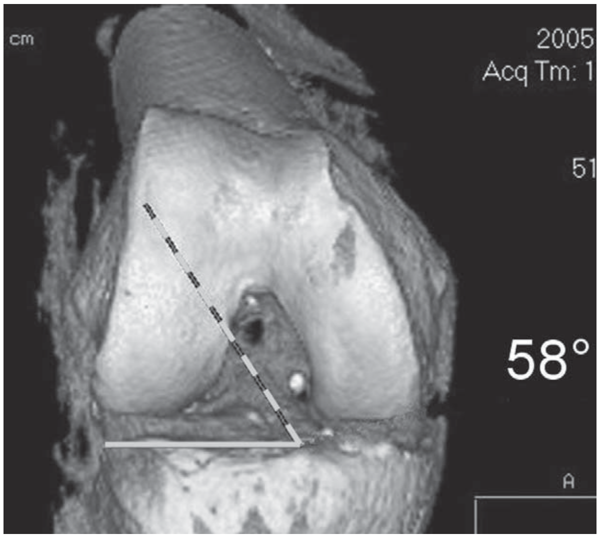

FIGURE 18. Coronal view of the knee at 85 to 90 degrees. The anterior cruciate ligament is oriented at 55 to 60 degrees with respect to the tibial plateau.

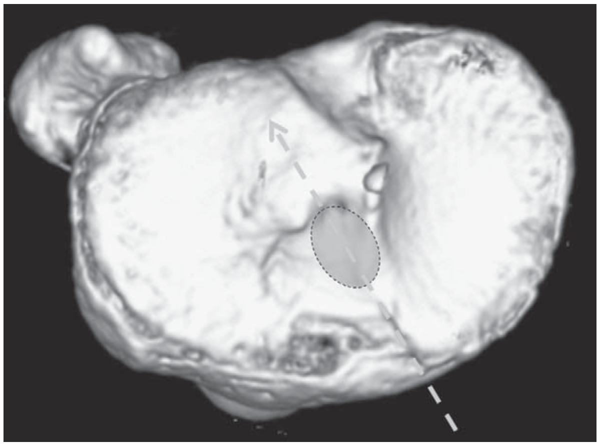

FIGURE 19. Orientation in the axial plane can be estimated by placing a probe through the tibial tunnel to the footprint of the anterior cruciate ligament (ACL) origin on the femur. Dotted line and shaded area are the approximate footprint of the ACL insertion on the tibia.

the tunnel produced in which L = the long axis diameter, d = diameter of the drill bit used, and α = angle between drill bit and drilling surface in degrees (Fig. 17).

$$\mathrm{L} = \mathrm{d}/\mathrm{Sine}\,(\alpha^\circ) \tag{1}$$

Corresponding guide placement should reflect this distance by placing the guide pin at least 7.75 mm anterior to the intertubercle ridge if over drilling with a 10-mm reamer. A shallow tibial angle also tends to cause a relatively short tibial tunnel that may require a modification of the fixation technique as discussed later in this article.[10]

Orientation in the coronal plane was found to be approximately 58 degrees from the plane of the tibial plateau (Fig. 18) and can be accomplished by tilting the drill arm of the guide slightly laterally to approximate this angle. This measurement is slightly more than the 47.9 degrees (42.1 degrees to the longitudinal axis of the tibia) as recommended by Heming et al[10] and slightly lesser than the 65 to 70 degrees as recommended by Howell et al[18] to reduce the loss of flexion and anterior laxity.

Orientation of the guide pin in the axial plane can be estimated by placing a probe through the medial arthroscopy portal into the notch and aligning it with the ACL origin. As the arm of the guide will be entering the knee through the same medial arthroscopy portal, the orientation of the guide arm should be identical to the probe (Fig. 19). If the guide pin is angled too far laterally, the ACL graft will be more lateral than the anatomic origin and will risk lateral wall abrasion due to the oblong nature of the final hole. If the tunnel is oriented too medially, it will be difficult to access the lateral wall of the femoral tunnel, resulting in a femoral tunnel too high in the notch.

Once the tibial guide pin is placed, the tibial tunnel is created. The anterior tibial cortex is drilled to accommodate the diameter of the larger of the 2 bone blocks of the BTB graft. The intra-articular portion of this tunnel needs only to accommodate the smaller of the bone blocks as the graft is passed and therefore needs only to be drilled to that diameter.

Once the tibial tunnel is over drilled, a 45-degree arthroscopic awl can be placed through the tunnel to the preselected ACL spot and used to enlarge the femoral targeting spot to facilitate the guide-pin drilling. This maneuver can also assure a surgeon that the tibial tunnel is drilled appropriately so as to target the femoral targeting site with an endoscopic or transtibial approach.

I then place the knee in a Figure 4 position with the knee at approximately 90 degrees of flexion. This places a varus load on the knee and facilitates guide placement and subsequent drilling. The knee is left in this position through the remaining portion of drilling and graft passage, thereby simplifying subsequent steps.

A flexible nitinol wire guide pin (Smith & Nephew, Andover, MA) and flexible femoral drills (Smith & Nephew) is required to be used in this process. The use of flexible instrumentation helps accommodate any discrepancy between the angle of the tibial tunnel and the optimal position of the femoral tunnel. Flexible reamers should help prevent further over reaming of the tibial tunnel during femoral drilling and thereby changing the position of the tibial tunnel to a lesser than optimal position. The nitinol wire is placed through the tibial tunnel and directed to the preselected femoral position central at the old ACL origin site. This is drilled through the lateral wall of the notch and out the lateral cortex of the femur. The femoral tunnel is then drilled. It is started with the smallest-diameter reamer and worked up to the appropriately sized reamer. The small reamer lessens the risk of enlarging the tibial tunnel when drilling the femoral tunnel and moves the fixation point of the guide pin laterally as the tunnel is drilled. The flexible guide pins can thereby bend and accommodate the larger diameter reamers necessary for the bone plug, again to accommodate any discrepancy between the 2 tunnel positions. The outer cortex is then drilled and the graft can be passed from distal to proximal and fixed per the surgeon's preference. I use remote fixation with an

Endobutton (Smith & Nephew) is used proximally and screw and post fixation distally because of its simplicity and also to accommodate the variation in positioning of the patella bone block within the tibial tunnel. Owing to the shallow angles of the tunnels, the femoral and tibial tunnels are typically short. The tibial bone block is therefore occasionally longer than the tibial tunnel and not suitable for interference fit fixation. If the graft is too long for the tibial tunnel, the excess length outside can be accommodated by creating a small trough extending from the distal edge of the tibial tunnel. The use of remote fixation also equalizes the rigidity and strength of the fixation at both ends of the graft, thereby minimizing any pistoning that would occur with one end being more rigid than the other. The screw and post fixation system accommodates this without requiring a new tibial tunnel. In addition, a smaller patellar bone plug can be harvested without the need to accommodate interference fit fixation within the tibial tunnel, and this smaller bone block is both cosmetically more appealing and minimizes the risk of patellar fracture.

CONCLUSIONS

The 2-incision technique used to harvest the patellar tendon grafts as described in this article, has been shown to decrease the risk of anterior knee pain to a level comparable to HSTGs.[5] In addition, proper graft tunnel placement and orientation is integral to success. It is important to visualize the bony landmarks that should be used to ensure proper anatomic graft placement. Proper orientation in the sagittal, coronal, and axial planes should be used for the tibial tunnel to drill the femoral tunnel in an anatomic position and to perform a successful endoscopic transtibial tunnel ACL reconstruction.

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