ENDOSCOPIC FIXATION OF A DOUBLE-LOOLED SEMITENDINOSUS AND GRACILIS ANTERIOR CRUCIATE LIGAMENT GRAFT USING BONE MULCH SCREW

STEPHEN M. HOWELL, MC, USAFR,* and JOHN EIBE GOTTLIEB, MD†

Surgeons are switching to the four-bundled hamstring graft, composed of double-looped semitendinosus and gracilis tendons (DLSTG), to replace the torn anterior cruciate ligament (ACL). Mechanically, the DLSTG is superior; it is twice as strong and stiffer than a patella tendon graft, and the four bundles share load and mimic the function of the anteromedial and posterolateral bands of the native anterior cruciate ligament. Morbidity from tendon removal is minimal and by 3 months soreness disappears and isometric knee flexion strength returns to normal. It is safe for the patient to undergo aggressive rehabilitation without a brace and to return to sports activities at 4 months when the knee is reconstructed with a DLSTG graft. This report describes the rationale and technique for implanting the DLSTG in a femoral tunnel using rigid fixation instead of a compliant suture bridge. Fixation is achieved by looping the tendons over a post (Bone Mulch Screw) inside the femoral tunnel. The strength, stiffness, and biologic bond of the graft is enhanced by compaction of bone into the femoral tunnel through a bore in the Bone Mulch Screw.

KEY WORDS: anterior cruciate ligament graft, hamstring tendon, fixation

Autogenous bone patellar tendon bone has been the principal graft source for reconstructing a torn anterior cruciate ligament (ACL). Unfortunately, complications associated with graft harvest occur including patella fracture, patella tendon rupture, quadriceps tendon rupture, anterior knee pain, degeneration of the articular surface of the patella-femoral joint, quadriceps weakness, and arthrofibrosis.14 In several studies these complications pre-vented full functional recovery of a number of patients.5,5

To reduce this morbidity and increase the consistency of the clinical outcome surgeons are switching to autogenous double-looped semitendinosus and gracilis tendons (DLSTG) as a graft. Mechanically, the DLSTG is superior; it is twice as strong15–17 and stiffer15 than a patella tendon graft,18,19 and the four bundles share the load and mimic the function of the anteromedial and posterolateral bands of the native ACL.20 Morbidity resulting from tendon removal is minimal and by 3 months soreness disappears and isometric knee flexion strength returns to normal.21

A two-incision technique, in which the DLSTG was looped around a post within the tibial tunnel and fixed to the femoral cortex using a soft tissue washer and screw, allowed aggressive rehabilitation without a brace and a safe, early return to sports activities 4 months after the reconstruction.22 The stability and function using the two-incision technique in this study were as good or better than in studies that used patellar tendon as a graft.22

It is unknown if aggressive rehabilitation without a brace is safe when the DLSTG is inserted endoscopically and fixed using either a suture to bridge the graft to a fixation device23 or an interference screw to fix a multi-bundle hamstring graft wrapped around a bone plug (Bone-Hamstring-Bone) in a bone tunnel.23 Fixing the graft with buttons (Endobutton; Smith and Nephew, Mansfield, MA) or anchors (Mitek Ligament Anchor; Mitek Surgical Products, Norwood, MA) initially has only 21% and 11% of the strength and stiffness of the native ACL because the weak link is the suture that suspends the graft from the fixation device.15 Similarly, the bone plug construct has only 30% and 9% of the strength and stiffness of the native ACL (Figs 1 and 2).23

Because of our success using the DLSTG graft fixed over a post inside the tibial tunnel, and the limitations of other methods that are used to fix the graft endoscopically, a new method that relies on the Bone Mulch Screw (Arthrotek, Inc, Ontario, CA) to fix the graft over a post inside the femoral tunnel was developed (Fig 3). Fixation of the DLSTG with this device provides 52% of the strength and 93% of the stiffness of the native ACL.15 The compaction of the bone into the femoral tunnel through a bore in the center of the screw further increases the stiffness an additional 20%.15 Slippage cannot occur because the graft is looped over a post. Clinical trials have been completed in more than 400 patients between November 1993 and December 1995 by two surgeons (SMH and JEG), and our collective experience allows us to recommend this new surgical technique.

SURGICAL TECHNIQUE: RATIONALE AND DESCRIPTION

Place the Portals

Precise placement of the portals is necessary to use a tibial guide that customizes the placement of the tibial
tunnel and to directly view up through the femoral tunnel. The medial portal is used for inserting the One-Step Tibial Guide (Arthrotek, Inc) into the intercondylar notch and is placed so that it touches the medial edge of the patellar tendon (Fig 4). The lateral portal is made within the substance of the patellar tendon at the junction of the central and lateral third. The surgeon can look past the lateral femoral condyle and directly up through the femoral tunnel when the arthroscope is inserted through the lateral portal.

Harvest the Gracilis and Semitendinosus Tendons

Identifying and isolating the semitendinosus and gracilis tendons from neighboring tissues are the first steps in a successful harvest of the hamstring tendons. Maintain a clear view of the tissue planes by using a tourniquet. Center a 4- to 5-cm vertical incision 3 finger-widths distal to the medial joint line, midway between the anterior and posterior margin of the tibia. Use this incision for harvesting both tendons and drilling the tibial tunnel. Bluntly dissect the subcutaneous tissue off the sartorius fascia as far posterior as the popliteal space.

Palpate the gracilis, the most distinct tendon, which lies deep to the sartorius fascia and proximal to the semitendinosus tendon. Make an incision through the sartorius fascia inferior and parallel to the gracilis tendon; avoid a deep incision because this can cut into one of the tendons or the medial collateral ligament. Flex the knee to relax the hamstring tendons. Use a finger to identify the gracilis
tendon at the medial edge of the tibia and bluntly dissect it from the surrounding tissue. Hook the tendon with your index finger or a right angle clamp and deliver it out of the incision. Loop a 3/8-in penrose drain around the tendon and use it to mobilize and retract the tendon. Sharply outline and detach the periosteal insertion of the gracilis tendon from the anterior crest of the tibia to provide an additional 1.5 to 2 cm of length and grasp the end of the tendon with an Allis clamp. Suture 5 cm of the insertion with a 36-inch-long 1-0 absorbable suture using a stitch that crisscrosses the graft providing a Chinese finger trap effect (Fig 5).

The final step is to free the tendon of all fascial branches so that the body of the tendon is not amputated in midsubstance before all the muscle is stripped. Apply tension to the gracilis tendon with the knee in flexion. Use an index finger to circumferentially palpate the tendon into the popliteal fossa and identify any branches that course inferior and posterior. Cut these branches. Incomplete removal may cause the tendon stripper to follow one of the branches and prematurely amputate the tendon. Tug on the sutured end of the tendon. If the tendon moves freely in and out of the incision and the skin overlying the popliteal fossa dimples, then all the branches should be released. Use a dull, closed-end tendon stripper (Arthrotek, Inc) to strip the muscle from the tendon. The gracilis tendon is identified by muscle tissue on both sides of the tendon.

The same technique is used to isolate and remove the semitendinosus tendon that lies distal or inferior to the gracilis tendon. Up to four, distinct, fascial branches can arise from the inferior edge of the semitendinosus tendon. In contrast to the gracilis tendon, muscle is present on only one side of the semitendinosus tendon.

Prepare the Double-Looped Hamstring Graft
Each tendon must taper from its midpoint to its origin or muscular end to prevent the graft from hanging up when it is passed through the knee. Remove muscle from both tendons using a periosteal elevator. Trim the flat, leaf-like origin of the semitendinosus tendon so that it gradually tapers from the middle to the origin. Form this origin into a compact tube and maintain this shape by stitching it with a running 3-0 absorbable suture. Suture 5 cm of the origin with a 36-in-long 1-0 absorbable suture using a stitch that crisscrosses the graft forming a Chinese finger trap. The tendon will taper even further when tension is applied to this stitch. The gracilis tendon has a thinner origin and does not need to be formed into a tube. Use a different color suture, but the same suturing technique, to sew the origin of the gracilis tendon.

Size the Double-Looped Hamstring Graft
Form a four-bundle graft by looping the middle of both tendons over an umbilical tape. Pull the umbilical tape and double-looped graft through a series of sizing sleeves (Sizing Sleeve; Arthrotek, Inc) (Fig 6). The diameter of the smallest sizing sleeve that freely passes over the graft without friction is used to select a drill for reaming the tibial and femoral tunnels.

Fig 5. A 36-inch 1-0 absorbable suture is sewn using a criss-cross stitch to create a Chinese finger trap effect. Pulling on the suture causes the tendon to taper, which helps it pass easily around the post.
Tibial Tunnel Placement: Rationale

Reconstructed knees regain more extension, have less pain and effusions, and have better stability when ACL grafts are placed without roof impingement (Fig 7). To avoid these complications, the center of the tibial tunnel should be positioned 4 to 5 mm posterior and parallel to the slope of the intercondylar roof with the knee in full extension. Because the slope of the intercondylar roof varies from 23° to 60° and knee extension varies from 30° of hyperextension to 2° of flexion, the placement of the tibial tunnel in the sagittal plane will have to be adjusted for each patient’s unique combination of roof angle and knee extension. The One-Step Tibial Guide (Arthrotek, Inc) has been engineered to customize the position of the tibial tunnel so the graft is positioned anatomically, an extensive roofplasty is avoided, and roof impingement is consistently prevented.

Insert the Tibial Guide

Remove the remnant of the torn ACL. Do not perform a roofplasty or wallplasty. Insert the One-Step Tibial Guide through the medial portal and position its tip between the posterior cruciate ligament and lateral femoral condyle (Fig 8). The guide centers itself in the notch because the tip is constrained between these two structures. Advance the guide further into the intercondylar notch while slowly extending the knee. Be certain the positioning bump remains inside the intercondylar notch while the arm of the guide is brought to lie against the trochlear groove. Place the heel on a Mayo stand to maintain the knee in hyperextension. Drain the irrigation fluid from the joint and remove the arthroscope.

Seat the Tibial Guide and Drill the Kirschner Wire

Seat the guide against the trochlear groove by pulling the arm of the guide toward the ceiling with the long and ring fingers while simultaneously, passively hyperextending the knee by pushing the patella toward the floor with the hypothenar surface of the same hand. Three-point fixation customizes the orientation of the guide; the positioning post rests on the lateral eminence, the positioning bump...
is against the intercondylar roof, and the arm of the guide abuts the trochlear groove (Fig 9). Insert the drill sleeve into the guide and position the tip of the drill sleeve so that it contacts the tibia midway between the anterior and medial edge of the tibia. Drill a 2.4-mm drill tip Kirschner wire until it penetrates the subchondral bone of the tibial plateau.

**Assess the Placement of the Kirschner Wire**

Remove the guide and tap the Kirschner wire 1 to 2 cm into the joint. In the coronal plane, the Kirschner wire should be 1 to 2 mm lateral to the lateral edge of the posterior cruciate ligament with the knee at 90° of flexion. In the sagittal plane, there should be 2 to 3 mm of space between the intercondylar roof and Kirschner wire, which can be confirmed with a nerve hook or with a lateral roentgenogram performed while the knee is in hyperextension. Drill the tibial tunnel using a cannulated reamer that has been passed through the same sizing sleeve used to determine the diameter of the graft. Collect reamings within the sizing sleeve; they will be used later for bone grafting the femoral tunnel.

**Eliminate Notch Impingement**

Place the knee in maximum extension. Insert an impingement rod (Impingement Rod; Arthrotek, Inc) the same diameter as the tibial tunnel through the tibial tunnel and into the notch. If passage is obstructed, impingement exists. Perform a roofplasty and wallplasty using the roof gouge and angled wall osteotome. Confirm the notch has been adequately expanded by freely passing the impingement rod into the notch with the knee hyperextended (Fig 10).

**Femoral Tunnel Placement: Rationale**

In the endoscopic technique, the placement of the femoral tunnel is controlled by the position of the tibial tunnel because the aimer for selecting the location for the femoral tunnel is passed through the tibial tunnel (Fig 11). Adjusting changes in graft tension by fine tuning femoral tunnel placement is severely limited with the endoscopic technique.

To determine if the endoscopic technique produced consistent tensions in the graft, the tension in the DLSTG graft was measured from 0° to 90° in 14 patients in the operating room. The endoscopic technique, as described in
this article, was found to provide consistent tension patterns in the graft that were similar to the normal ACL.20

Insert the Femoral Aimer

Prepare the notch by removing all soft tissue from the posterior ledge of the intercondylar roof with an angled curette. Insert an endoscopic femoral aimer (Arthrotek Size Specific Femoral Aimer; Arthrotek, Inc) that matches the diameter of the graft through the tibial tunnel and hook the tip over the posterior ledge of the intercondylar roof (Fig 11). Orient the aimer at the 11-o’clock position for the right knee and at the 1-o’clock position for the left knee. Lock the guide in place by allowing the knee to flex to 70° to 90°. Drill a 25-mm femoral tunnel using an endoscopic reamer (Cannulated End Cutting Reamer; Arthrotek, Inc).

Place the U-Shaped Drill Guide

Assemble the U-guide (U-shaped Drill Guide; Arthrotek, Inc) by securing an insertion rod the same diameter as the femoral tunnel to the body of the U-guide. Place the knee at 70° to 90° and insert the U-guide through the tibial tunnel and intercondylar notch and 25 mm into the femoral tunnel. Insert the calibrated aiming bullet into the U-guide and rotate the U-guide so that the bullet touches the skin anterior to the lateral epicondyle. Mark the skin and make a 12-mm-long incision through the skin, iliotibial band, and periosteum directly to the bone. Twist the bullet through the incision until it rests against bone. Lock the bullet against the bone by tightening the knurled knob (Fig 12). Determine the length of the Bone Mulch Screw by reading the mark on the bullet from the side of the U-guide that faces the skin. If the skin side of the U-guide intersects the bullet between the 25 mm and 30 mm marks use a 25-mm screw, and if the intersection is between the 30 mm and 35 mm marks use a 30-mm screw.

Drill the Tunnel for the Bone Mulch Screw

Drill a 2.4-mm drill-tipped Kirschner wire through the bullet until it stops against the lateral side of the insertion rod. Disassemble and remove the U-guide. Look directly up through the femoral tunnel by inserting the 30° arthroscope through the lateral portal. Tap the Kirschner wire across the femoral tunnel. Accept the position if the Kirschner wire is within 1 mm of bisecting the femoral tunnel; if not, redrill. Drill the tunnel for the Bone Mulch Screw using an 8-mm cannulated reamer. Advance the reamer over the Kirschner wire and catch the bone reamings in a sizing sleeve. The reamer should be drilled across the width of the femoral tunnel, but not into the medial wall (Fig 13).

Expand the Proximal End of the Femoral Tunnel

Insert the motorized shaver through the Bone Mulch Screw tunnel and vacuum bone debris from the femoral tunnel. If the Kirschner wire was slightly anterior or posterior, remove 1 to 2 mm of bone from the anterior or posterior wall to increase clearance during passage of the graft. Bone can be removed by manipulating an angled curette inserted through the Bone Mulch Screw tunnel.

Insert the Bone Mulch Screw

Insert the 6.4-mm screwdriver into the Bone Mulch Screw. Orient the slot on the screwdriver so that it is in line with the notch on the screw head and the mouth opening at the tip of the screw (Fig 14). Cut threads in the tunnel by screwing the Bone Mulch Screw until the tip is imbedded...
2 to 3 mm into the medial wall of the femoral tunnel. Back out the screw so that its tip is only two thirds of the way across the femoral tunnel.

**Place the Suture to Pass the Graft**

Thread a 24-inch, monofilament, 1-0 suture through the Suture Loop Passer (Arthrotek, Inc) (Fig 15). Maneuver the device through the tibial tunnel into the femoral tunnel and position the suture loop around the tip of the Bone Mulch Screw. Advance the screw across the femoral tunnel until the tip is imbedded 2 to 3 mm into the medial wall of the femoral tunnel and the groove on the screwdriver is facing the intercondylar notch. Remove the suture passer without twisting it and secure the anterior limb of the suture to the drape, proximal to the patella. Do not twist the suture because this will cause the graft to tangle during passage.

**Pass the Graft**

Select the muscle end of the two tendons and tie the posterior limb of the passing suture to the two color-coded sutures attached to the tendons. Pull the sutures through the tibial tunnel, posterior to the tip of the Bone Mulch Screw, around the tip, and back down the tibial tunnel.

Remove the passing suture and even the lengths of the graft. Apply constant, firm tension to the sutures and pull both tendons through the knee and around the fixation post. If the tendons hang up, back out both tendons a few centimeters and pull the semitendinosus through first and follow with the narrower, gracilis tendon (Fig 16). Adjust the position of each tendon until the limbs exiting the tibial tunnel are equal in length.

**Secure the Graft**

Apply tension to all four limbs of the graft as they exit the tibial tunnel, and cycle the knee from 0° to 90° to remove slack. Hyperextend the knee, apply tension, and secure the graft to the tibia with a soft tissue washer and bicortical screw. Remember to add 6 mm to the length of the cortical screw to account for the thickness of the washer and graft.

**Assemble the Bone Delivery System**

Remove the irrigation fluid from the knee and insert the bone compaction sleeve into the end of the Bone Mulch Screw (Fig 17). The bone graft compaction rod is then tapped through the sleeve and body of the screw until it reaches the bottom of the screw. Examine the marks on the compaction rod at the opening of the bone mulch delivery.
sleeve. The sleeve is fully seated when the mark on the compactor rod that matches the size of the screw is in line with the edge of the bone compaction sleeve.

Compact Bone Graft Into the Femoral Tunnel

Remove the compactor rod and sprinkle bone into the bone compaction sleeve. Use the bone mulch obtained from reaming the tibial and Bone Mulch Screw tunnels. Drive the bone across the screw and into the femoral tunnel by gently tapping the compaction rod with a mallet until it bottoms out at the base of the screw. Repeat this step until all the bone graft is used. Verify that all the bone mulch has been cleared from within the bore in the Bone Mulch Screw by making sure that the mark on the compactor rod that matches the size of the screw is in line with the edge of the bone compaction sleeve (Fig 17).

Insert the Inner Screw Into the Bone Mulch Screw

Use a 3.5-mm hex screwdriver to insert the inner screw into the bore of the Bone Mulch Screw. Four counterclockwise revolutions of the screwdriver are required to seat the inner screw into the body of the Bone Mulch Screw. Do not continue to turn the inner screw once it seats because it will remove the Bone Mulch Screw. Use the 6.4-mm hex screwdriver to advance the Bone Mulch Screw one additional half turn. This leaves the channel opening at the tip of the Bone Mulch Screw facing superior, away from the intercondylar notch.

COMMENT

This surgical technique, composed of a DLSTG, a customized tibial tunnel, an endoscopic femoral tunnel, and rigid, endosteal fixation using the Bone Mulch Screw, has provided a consistent outcome in our practices for the reconstructed knee. In almost every case the patient can expect to return to sports activities by 4 months. In some selected patients, return has been possible at 2 months. Because this technique has not been used until recently we have not yet tabulated our 2-year outcomes.

Although 2-year data are lacking at this time, other studies have been performed to support each step of this surgical technique. The DLSTG is the strongest autogenous graft available and its strength is not affected by the age of the patient. Morbidity from harvest is minimal. Customized placement of the tibial tunnel places the graft anatomically, minimizes the degree of roofplasty, and avoids the complications of roof impingement. Endoscopic placement of the femoral tunnel through a customized tibial tunnel produces tension in the graft that is consistently similar to the native ACL. The Bone Mulch Screw provides the strongest and stiffest endoscopic fixation available for an ACL graft. Compaction of bone through the screw around the graft further increases the stiffness by 20%. Brace-free rehabilitation with early return to sports activities at 4 months is safe with a DLSTG graft.

REFERENCES


