6 Anterior Cruciate Ligament Reconstruction with Six-Strand Hamstring Tendon Graft

S Orduna, N Darwich, and C Butcher

Introduction

The gold standard autograft, the patellar tendon autograft (BTB), has been used for many years and is still the choice for many surgeons. Due to the low donor site morbidity, improvements of soft tissue graft fixation techniques, and satisfactory clinical outcome studies, we use a hamstring tendon graft. In this chapter, we describe our current surgical technique for performing ACL reconstruction using a six-stranded autogenous, triple gracilis, triple semitendinosus graft (TGST).

Diagnosis and Imaging

In addition to a detailed history and examination, the diagnosis is confirmed by MRI and KT 2000 arthrometer measurements comparing both knees. We look for associated posterolateral corner or meniscal injuries and malalignment on full-length standing radiographs, all of which may lead to a failure of the ACL reconstruction.

Graft Choice

Graft choice includes hamstring tendons, patellar tendon, or the quadriceps tendon. Allograft tendons are used for special conditions.

Hamstring tendon graft is our choice for the following patients:

- Patients whose occupation, lifestyle, or religion requires "knee walking," crawling, or kneeling
- Patients with a history of a patellofemoral pain or patellar tendinopathy
- Patients with open growth plates

The only absolute contraindication to the use of homolateral hamstring tendon grafts for ACL reconstruction is previous surgery done using the hamstring tendons.

Surgical Technique

Anesthesia and Positioning

Most of our patients receive regional anesthesia, especially adductor nerve blocks for postoperative pain management. A first-generation cephalosporin is administered intravenously.

A thigh-length anti-embolism stocking and a foam rubber heel pad are applied to the contralateral 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 with a thigh support and two foot supports. The contralateral side 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, allowing the medial compartment to be opened for meniscus or other surgery. The lower extremity is positioned so that a full, free range of motion can be performed during the procedure (Figs. 6.1, 6.2, 6.3, and 6.4). Full flexion of the knee will be required for drilling the femoral tunnel through the anteromedial portal, without risk of cartilage damage to the cartilage of the medial femoral condyle.

Surface markings are drawn for patella, patellar tendon, anterolateral and anteromedial portals, and the hamstring harvesting approach (Fig. 6.5).

We are pleased to include this invited chapter on ACL reconstruction with hamstrings. We do not perform this procedure, but due to the popularity of the procedure, we include this detailed description.

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P Neyret et al. (eds.), *Surgery of the Knee*, https://doi.org/10.1007/978-3-030-19073-6_6

Fig. 6.1 Extension position

Fig. 6.2 90° position

Fig. 6.3 120° position

A solution of 5 mg of morphine sulfate with 20 mL of 0.25% bupivacaine and 1:100,000 epinephrine is injected into the suprapatellar pouch for pre-emptive analgesia. 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.

Fig. 6.4 Full flexion

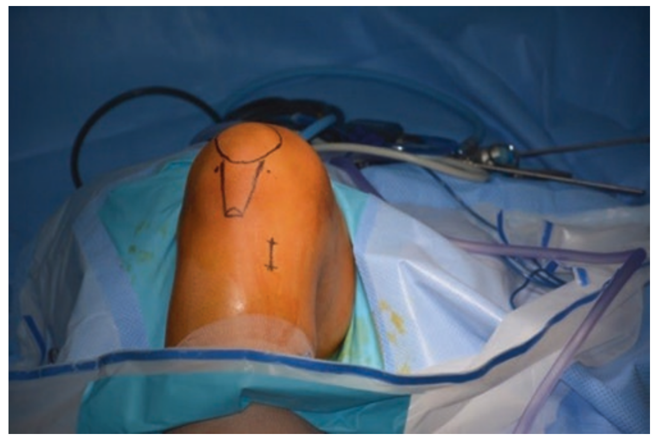

Fig. 6.5 Surface markings

Hamstring Tendon Graft Harvest

Harvest of the hamstring tendons is performed through a longitudinal skin incision centered over the tibial insertion of the hamstrings tendons (Fig. 6.6). The landmark for 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.

The incision is positioned close to the anterior crest of the tibia, easily allowing extension for the harvest of a patellar tendon graft in the case of premature amputation of the semitendinosus tendon graft. In revision cases where a BTB graft was used for the primary procedure, we extend the previous patellar tendon incision 2–3 cm distal to the tibial tubercle to allow harvest of the hamstring tendons and removal of the previous hardware.

Scissors are used for the dissection of the subcutaneous tissues to reduce the risk of damage to the infrapatellar branches of the saphenous nerve, avoiding the scalpel for this part of the procedure.

The sartorius fascia is exposed by blunt dissection. While an Allis-Adair tissue forceps is used to grab the distal

Fig. 6.6 Vertical incision

Fig. 6.7 Distal tendons grabbed with Allis-Adair tissue forceps and incision of sartorius fascia

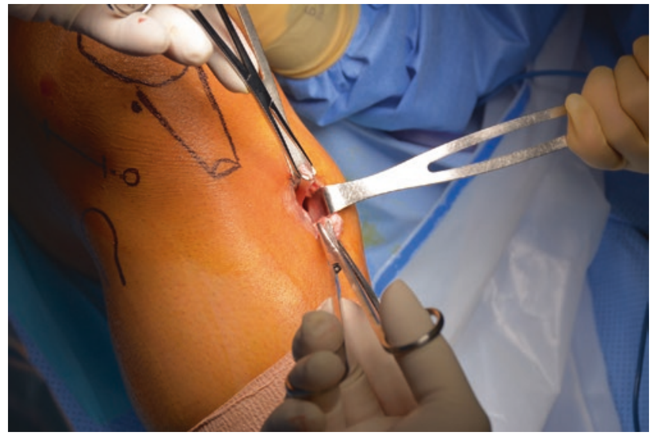

Fig. 6.8 Extension of the fascial incision longitudinally with scissors

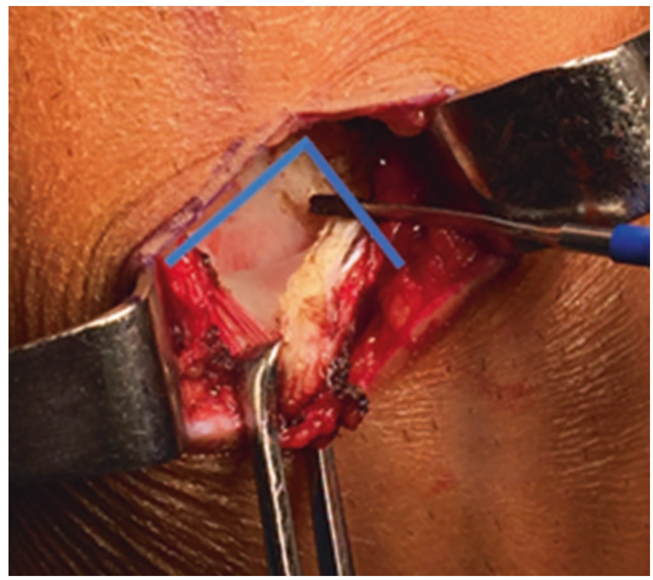

Fig. 6.9 Inverted L-shaped incision through the Sartorius using the cautery

tendons, a transverse 1 cm incision is made in the fascia proximal to the superior border of the sartorius tendon (Fig. 6.7). This is extended proximally with scissors, giving a view of the deep aspect of the pes anserinus (Fig. 6.8).

The conjoined tibial insertion of the two tendons is detached from the tibia by making an inverted L-shaped incision in the sartorius insertion using the cautery and scalpel (Fig. 6.9). The sartorius fascia is grasped with an Allis clamp and lifted away from the tibia, and the underlying medial collateral ligament is visualized and protected (Fig. 6.10). The tibial insertion of the two tendons is sharply released from the crest of the tibia with scalpel.

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 (Fig. 6.11). The gracilis tendon is sharply divided and grasped with a wide Allis-Adair tissue forceps and then freed from the undersurface of the sartorius fascia with the knife (Fig. 6.12).

Carefully the interconnecting fascial bands that run between the two tendons are released (Fig. 6.13). Sharp or scissors dissection along the superior border of the gracilis is avoided to prevent injury to the saphenous nerve.

A running suture (approximately five throws) is placed in the free end of the gracilis tendon with a No. 2 nonabsorbable suture (Fig. 6.14). While maintaining strong traction, remaining fascial bands are released with the index finger.

A closed tendon stripper is used to harvest each tendon (Figs. 6.15 and 6.16). The gracilis tendon is harvested first, by flexing the knee to 90° 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

Fig. 6.10 The sartorius fascia is grasped with an Allis clamp and lifted away from the tibia

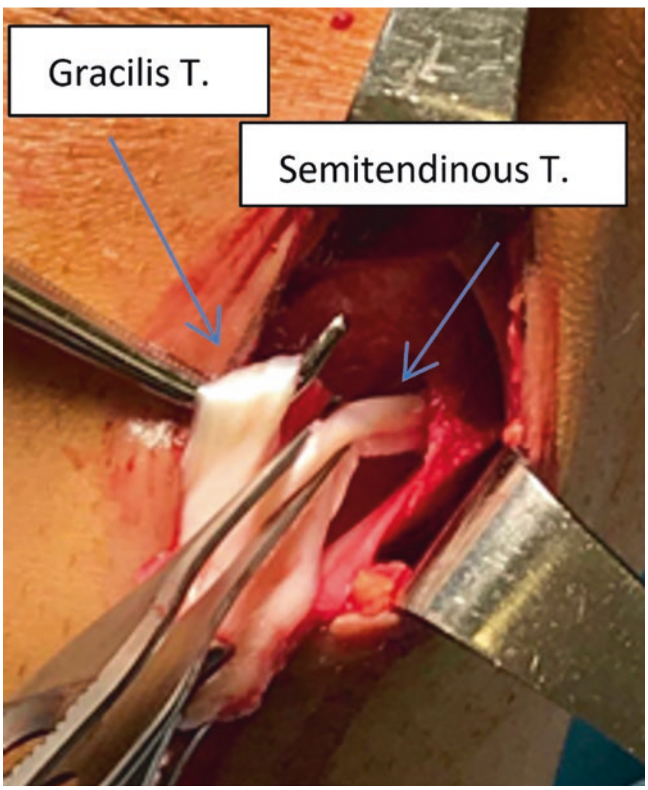

Fig. 6.11 A right-angled-type clamp is used to separate the two tendons

that extend from the inferior border of the semitendinosus tendon to the medial head of the gastrocnemius. These fascial connections must be released with the scissors to prevent premature amputation of the semitendinosus tendon.

Premature amputation of the semitendinosus tendon can result if the tendon stripper passes away from the tendon's normal path. If excessive resistance is encountered in

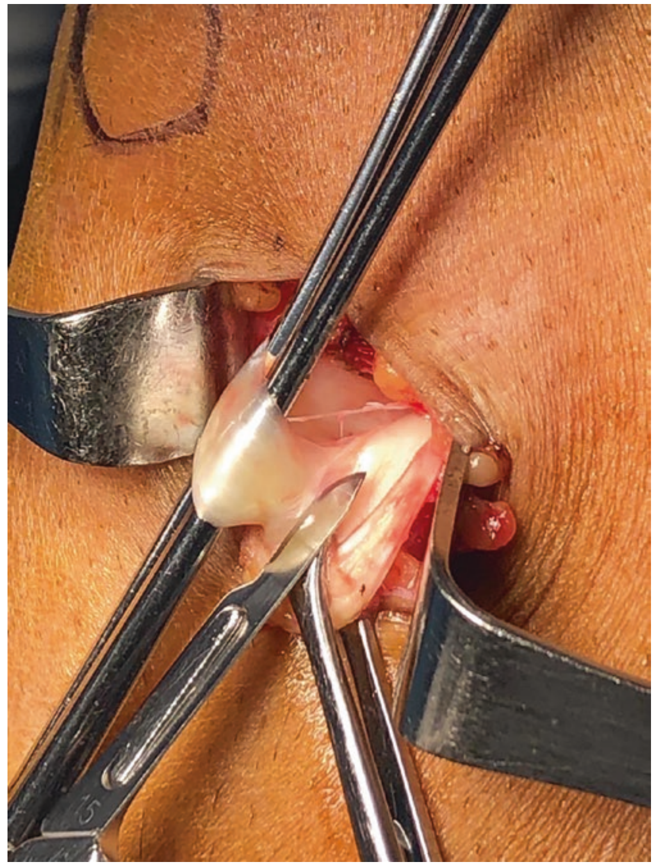

Fig. 6.12 The knife is used to free the tendon

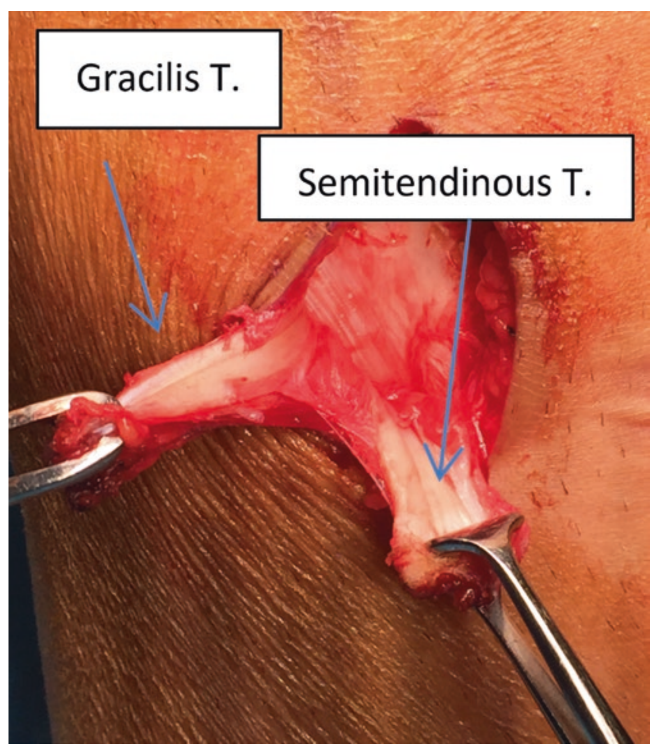

Fig. 6.13 Gracilis and semitendinosus tendons

attempting to advance the tendon stripper, the tension and force on the tendon and stripper are decreased, and then the tendon is re-tensioned before pushing the stripper again. Rotational movements may help to advance it around the tendon. A successful graft harvest typically results in graft lengths of 20–26 cm for the gracilis and 24–30 cm for the semitendinosus tendon.

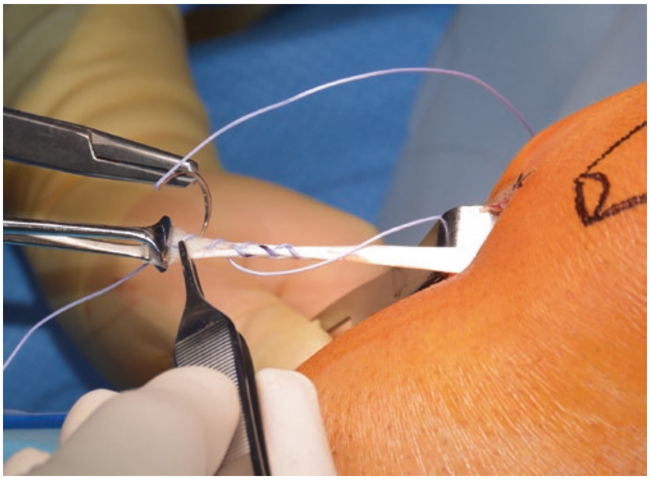

Fig. 6.14 A running suture (approximately five throws) is placed in the free end of the gracilis tendon

Fig. 6.15 Closed tendon stripper applied to the gracilis

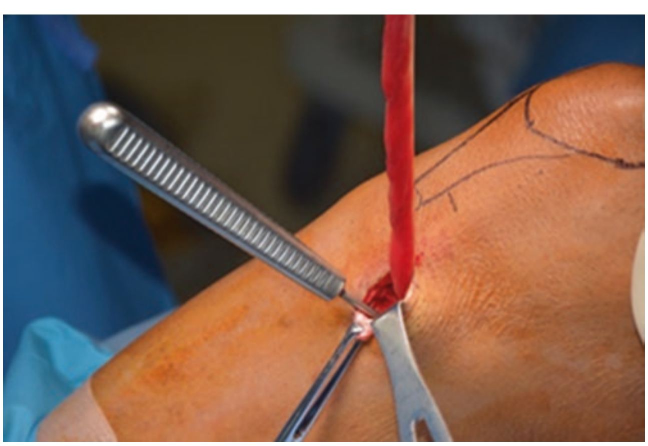

Fig. 6.16 Harvesting the tendon

Preparation of the Six Bundled Hamstring Tendon Graft

As soon as the gracilis tendon is harvested, the assistant starts the graft preparation while the surgeon changes gloves and completes the semitendinosus tendon harvesting (Fig. 6.17).

The grafts are placed on a preparation board (Smith and Nephew Graftmaster III), and residual muscle fibers on the proximal end of both tendons are removed by blunt dissection with a metal ruler, a large curette, or one arm of a sharp scissors (Fig. 6.18).

The proximal end of each tendon is tubularized with a continuous No. 2 nonabsorbable suture, and the sutures are tensioned (Fig. 6.19).

The tubularized proximal ends of each graft are sutured to the center of a polyester tape (Fig. 6.20).

The EndoButton device is inserted into its clamp and the whipstitches from the distal end of the gracilis, and the semitendinosus tendons are tied to the loop (Figs. 6.21, 6.22, and 6.23).

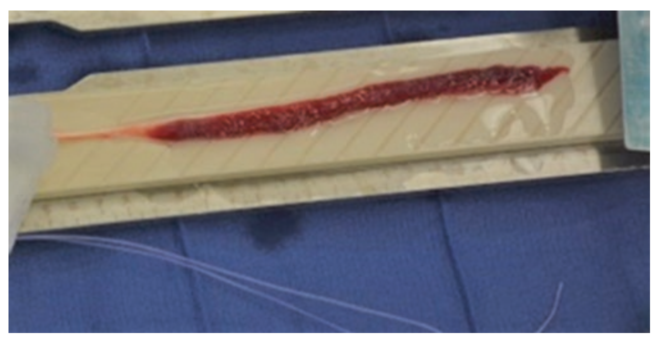

Fig. 6.17 The tendon laid out on a preparation board

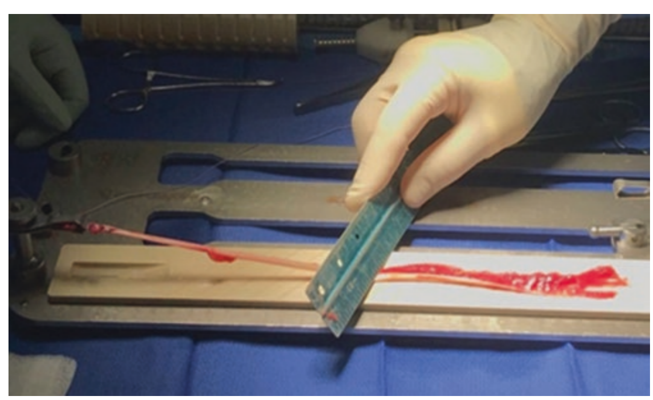

Fig. 6.18 The residual muscle fibers are removed

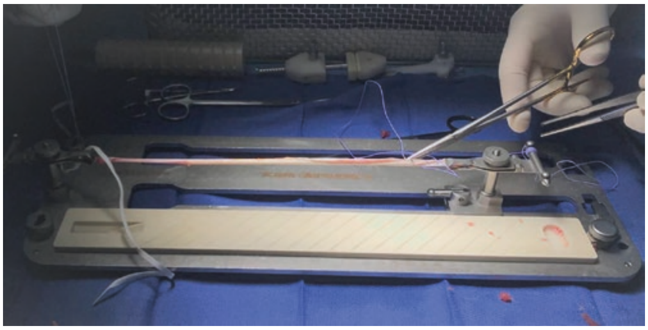

Fig. 6.19 The proximal end of each tendon is tubularized

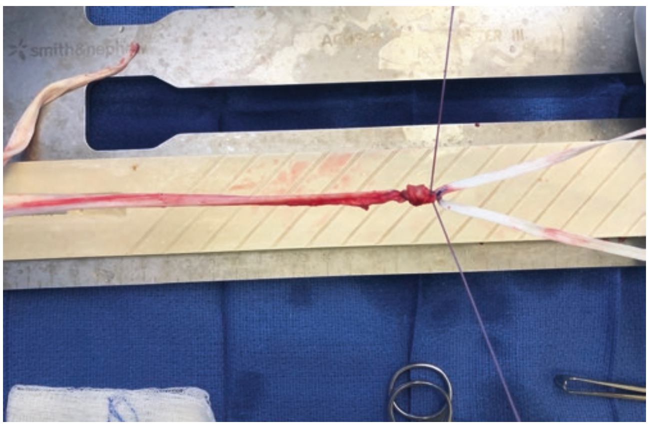

Fig. 6.20 The distal ends of each graft are sutured to the center of a polyester tape

Fig. 6.21 EndoButton device in the Smith and Nephew clamp

The proximal end of each tendon, with the polyester tape, is passed through the endobutton loop, creating a loop in the graft (Fig. 6.24). Then by passing one limb of the polyester tape on either side of the loop in the graft, a triple-strand graft is created (Figs. 6.25 and 6.26). The tape and the suture from the tubularized graft are then tied to the loop (Fig. 6.27).

The same process is repeated for the semitendinosus tendon (Figs. 6.28 and 6.29).

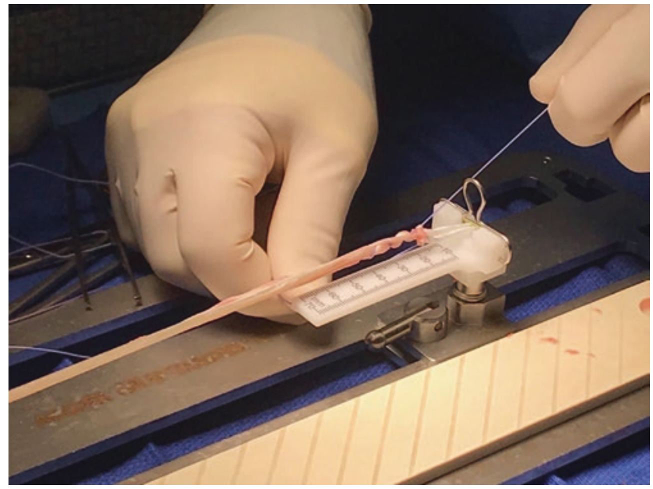

Fig. 6.22 Whipstiches from the proximal end of the gracilis and semitendnosus tendons are tied to the EndoButton loop

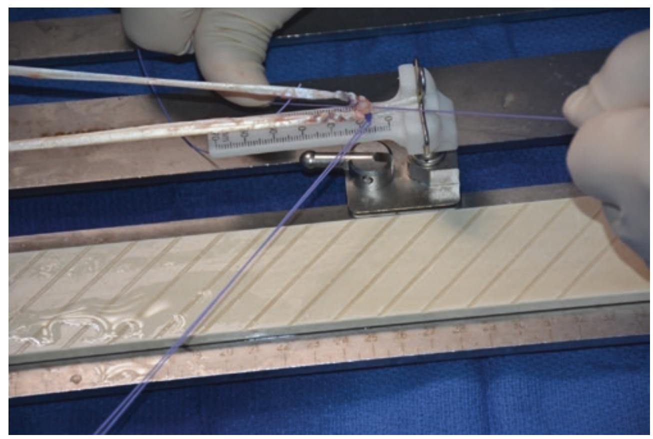

Fig. 6.23 The proximal ends of both tendons have now been sutured to the EndoButton loop

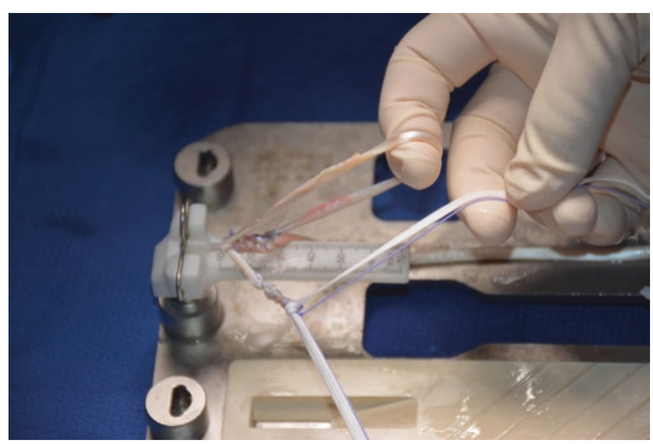

Fig. 6.24 Passing the distal end of the tendon through the EndoButton loop creates a loop in the graft (shown here held in the surgeon's index finger)

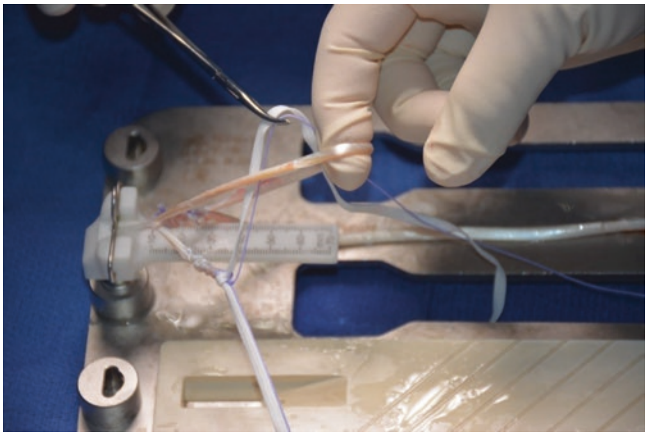

Fig. 6.25 Passing one limb of the polyester tape either side of the graft loop

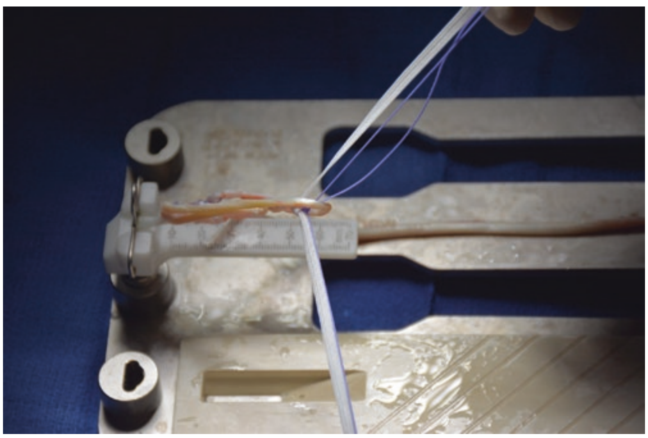

Fig. 6.26 Triple-bundle gracilis tendon

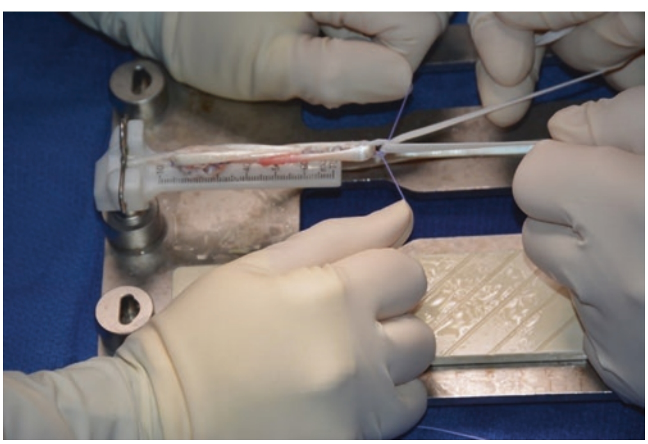

Fig. 6.27 Tying the tape and suture to the tendon loop

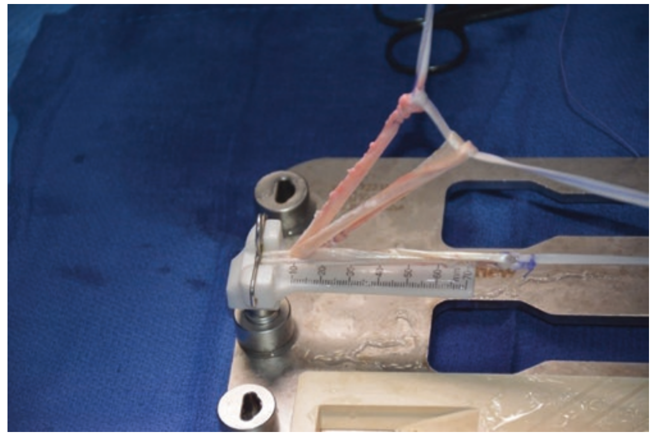

Fig. 6.28 Polyester tape being passed around the graft loop of semitendinosus tendon (above), and completed gracilis tendon (below)

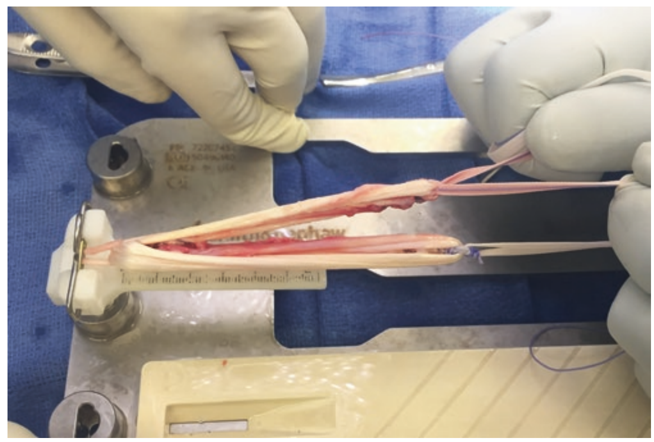

Fig. 6.29 Triple semitendinosus and gracilis grafts completed

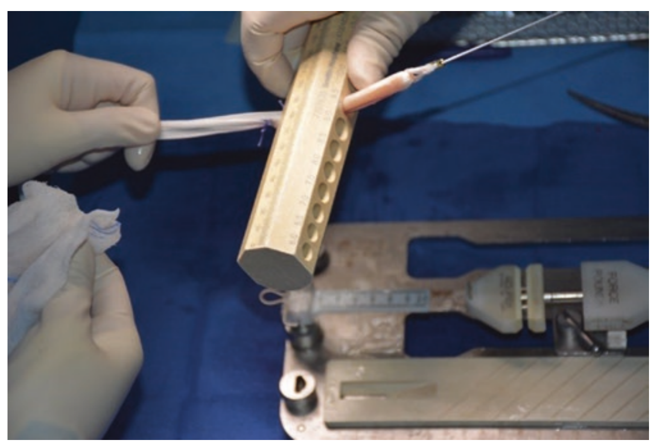

Fig. 6.30 The diameter of the graft is measured

The diameter of the TGST graft is measured with the 0.5 mm incremental sizing block or sizing tubes (Fig. 6.30).

The graft is covered with an antibiotic-soaked swab (vancomycin) and pretensioned at 15–20 pounds on the graft preparation board for the remainder of the procedure (Fig. 6.31).

After pretensionning, the six tendon strands are sutured together for 30 mm proximally and 20 mm distally with No. 2 nonabsorbable suture, in order to obtain better fixation with the rigid fix pins in femoral tunnel and the interference screw in the tibial tunnel (Fig. 6.32). After measurement of the fem-

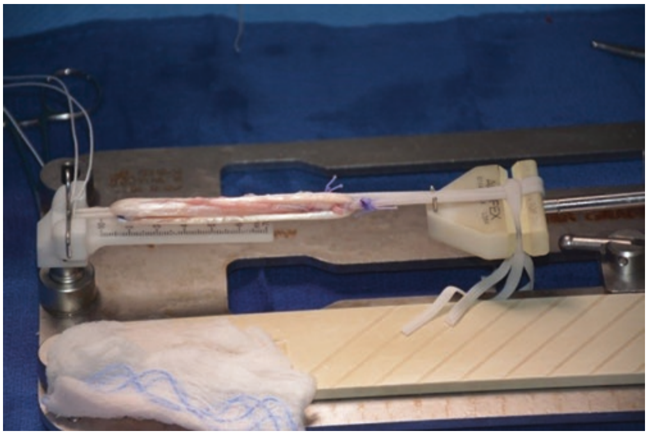

Fig. 6.31 Pretensionning of the graft

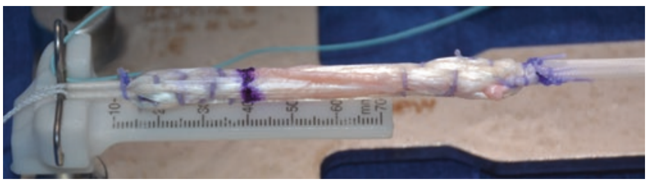

Fig. 6.32 The six strands are sutured together for 30 mm proximally and 20 mm distally

oral tunnel, the graft will be marked at the appropriate levels, to aid appropriate positioning of the graft. The polyester tapes facilitate strong traction during tensioning and fixation and can be used for additional tibial fixation with a staple.

Arthroscopic Portal Placement

We use two, or possibly three, portals (Fig. 6.5). A routine high anterolateral portal at the level of the inferior pole of the patella and adjacent to the lateral border of the patellar tendon is used for viewing. This portal gives a frontal view of the femoral attachment site of the ACL and is helpful in determining the clock orientation and the anatomic 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 patella tendon is used for instrumentation and viewing of the medial wall of the lateral femoral condyle if necessary.

We may extend the anteromedial portal distally for a few millimeters for drilling the femoral tunnel, but an accessory medial portal located inferior to the anteromedial portal at the level of the medial joint line is occasionally used if access to the femoral footprint is difficult. 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 avoiding damage to the medial meniscus.

Placement of the portal too medially produces a shorter femoral tunnel and risks injury to the medial femoral condyle by the endoscopic drill. Dilatation of the portal with the blunt arthroscope obturator followed by the Metzenbaum scissors helps ease future passage of instrumentation (Fig. 6.33).

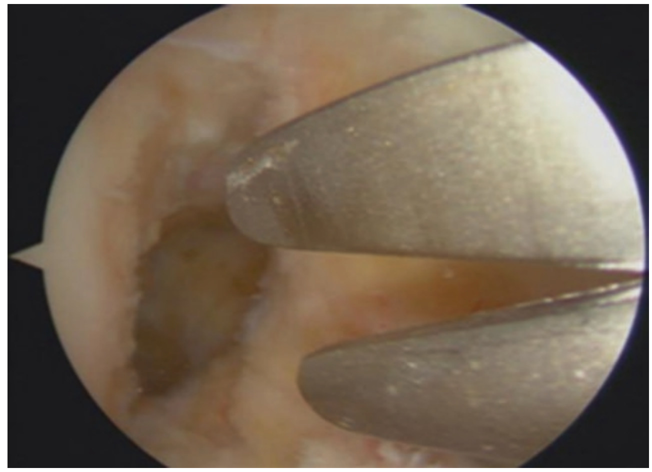

Fig. 6.33 Dilatation of the anteromedial portal with scissors

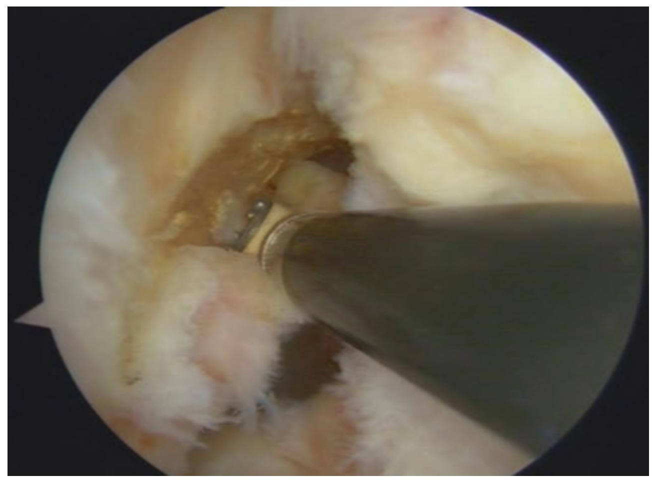

Fig. 6.34 Radiofrequency pencil from anteromedial portal removing remaining ACL from the lateral wall

We will change the scope from anterolateral to anteromedial portals to look for previously undetected injuries, for example, capsulomeniscal ramp lesion injuries, meniscal root detachment, or osteochondral injuries.

Notch Preparation

After a routine diagnostic arthroscopy and treatment of any associated pathology, we start with the intercondylar notch preparation. 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 probe (Fig. 6.34). The radiofrequency probe is preferred to the shaver blade in order to coagulate and to remove the soft tissue along the lateral wall of the interondylar notch without damage to the bony anatomy. We feel it is not necessary to remove all the remaining fibers as they may have a biological role to play in proprioception.

Use of the anteromedial portal technique allows the femoral tunnel to be positioned freely, and more posteriorly (lower down) on the sidewall of the lateral femoral condyle than in the past. This results in a more horizontal orientation of the ACL graft, which may avoid posterior cruciate ligament impingement, and in most cases eliminates the need for a notchplasty. However, a selective notchplasty may be required in the case of congenitally narrowed notches, more frequent in female or in chronic cases with notch stenosis due to the development of notch osteophytes.

Femoral Tunnel

We aim for a femoral tunnel within the anterior medial bundle footprint, posterior to the intercondylar ridge, and proximal/deep to the bifurcate (resident's) ridge (see Fig. 5.24, Chap. 5), leaving a posterior wall of 3 mm. A microfracture awl is passed through the medial portal and used to make the starting point (Fig. 6.35).

Verification of the correct starting point can be made by swapping the camera to the anteromedial portal. An appropriate sized offset femoral aimer is passed through the medial portal; e.g. 7 mm offset in order to perform an 8 mm tunnel whilst preserving a 3 mm posterior tunnel wall. The posterior blade of the femoral offset aimer is placed in the over-the-top position, and the knee is slowly flexed to 120° (Fig. 6.36a, b). A 2.7-mm drill-tipped guide pin is positioned at the site of the microfracture awl penetration mark and drilled out

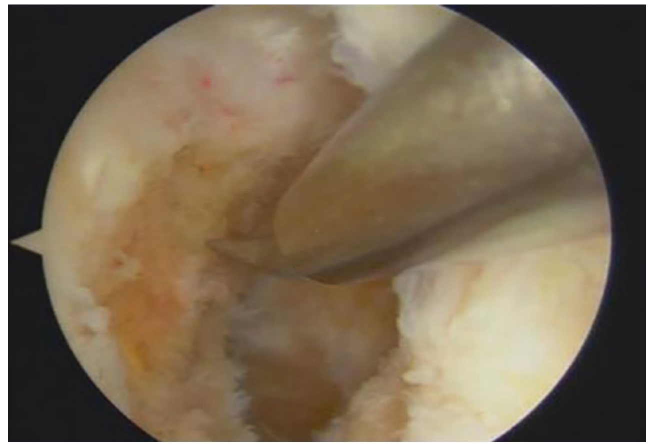

Fig. 6.35 A microfracture awl is passed through the accessory medial portal and used to make the starting point or footprint for the femoral tunnel

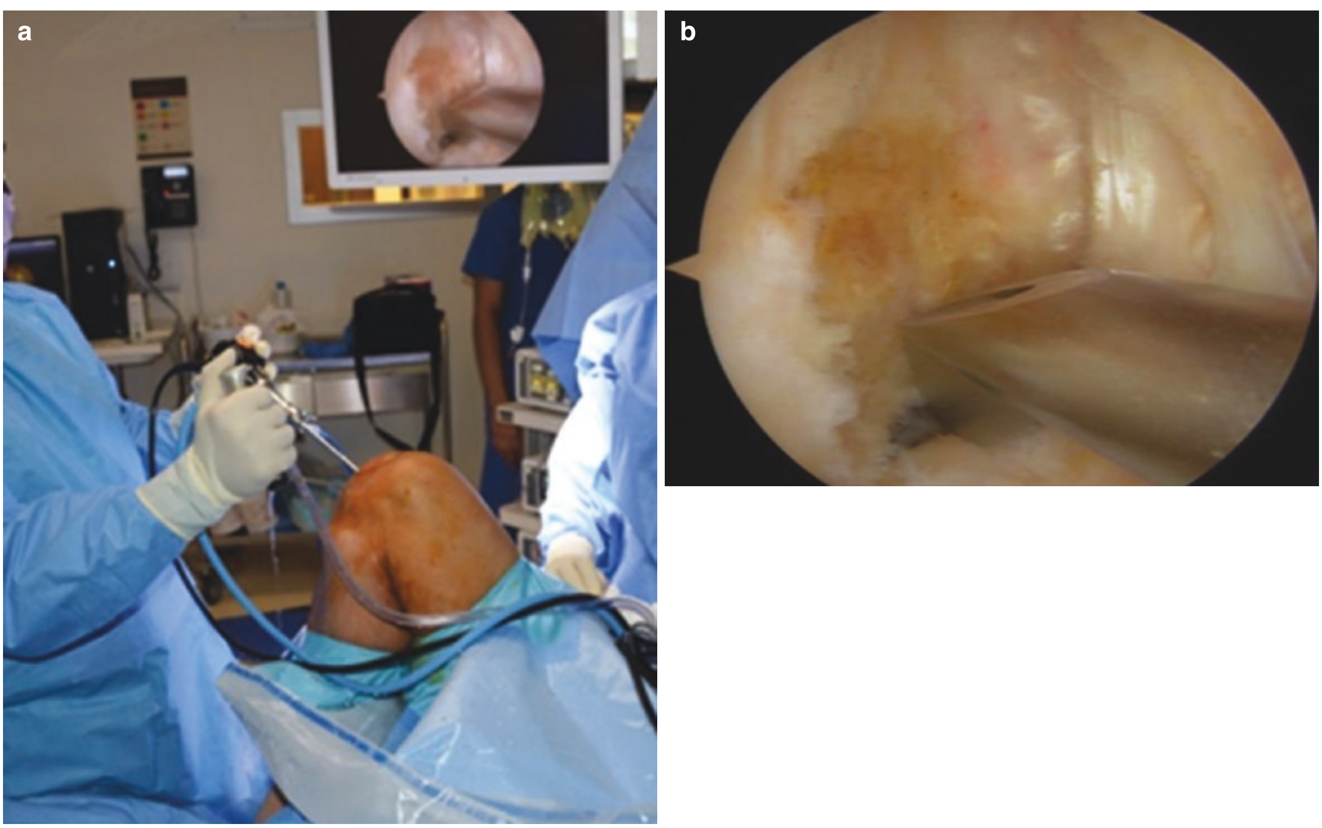

Fig. 6.36 (**a**) Femoral aimer entrance and view on screen in full flexion position knee. (**b**) Femoral aimer is placed in the over-the-top position

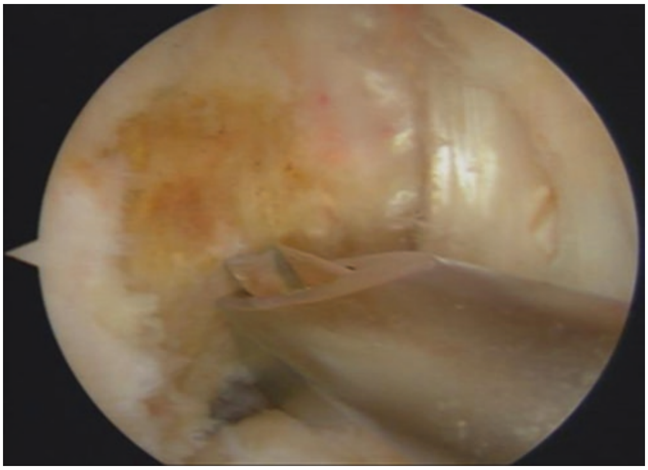

Fig. 6.37 The 2.7-mm drill-tipped guidewire is placed at the previously marked entry point

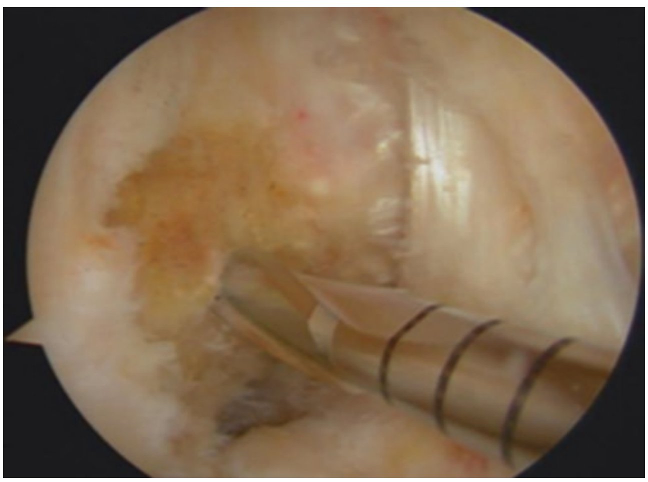

Fig. 6.38 4.5-mm EndoButton drilling through the femoral cortex

through the soft tissues of the lateral thigh (Fig. 6.37). Inadequate knee flexion can result in the guide pins coming to lie posterior to the intermuscular septum, placing the peroneal nerve at risk.

A 4.5-mm EndoButton drill (Smith and Nephew Endoscopy) is used to drill a tunnel through the lateral femoral cortex (Fig. 6.38), and the tunnel length is measured with a depth gauge (Fig. 6.39).

Tunnel drilling then proceeds progressively in 0.5 mm increments from 7 mm to the final size, which is equal to the measured proximal graft diameter. The femoral socket depth must allow for the length of the TGST graft (usually 25–30 mm) plus the extra 6 mm to allow the EndoButton to clear the lateral femoral cortex and to flip across the aperture. The articular edge of the femoral tunnel is smoothed with a rasp. The tunnel is then visualized arthroscopically, and the debris is removed from the knee with the shaver.

Next, the Rigidfix guide is introduced, and the two cross pin femoral tunnels are drilled from the medial side of the knee (Figs. 6.40 and 6.41). Their correct position is

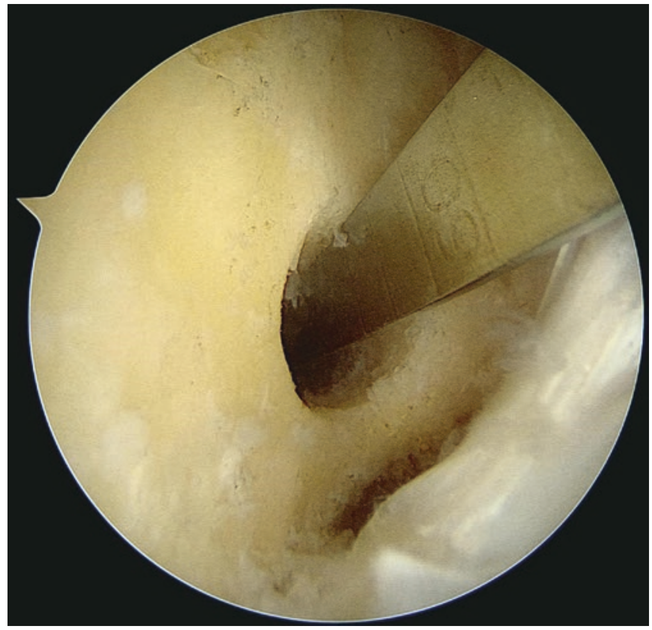

Fig. 6.39 Measurement of femoral tunnel length

Fig. 6.40 Introduction of Rigidfix femoral guide into the femoral tunnel

Fig. 6.41 Addition of the curved guide, and drilling of the femoral cross pin tunnels from the medial side of the knee

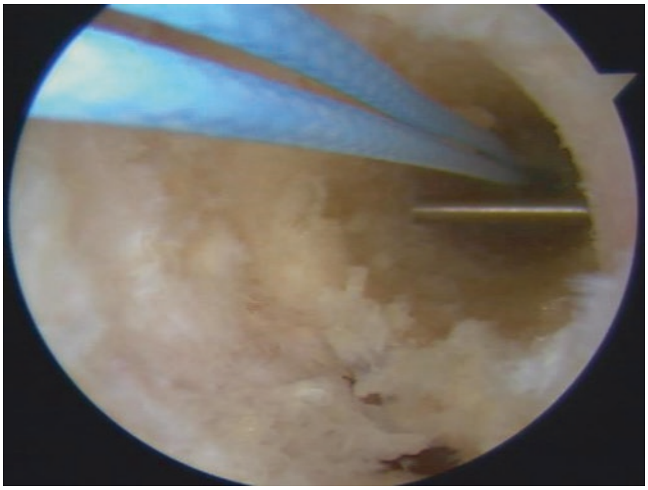

Fig. 6.42 Arthroscopic confirmation of the position of one of the Rigidfix tunnels

Fig. 6.43 Fluid emerging from the Rigidfix pins confirms that they are in the tunnel

Fig. 6.44 The adjustable tibial aimer is set between 50° and 55°

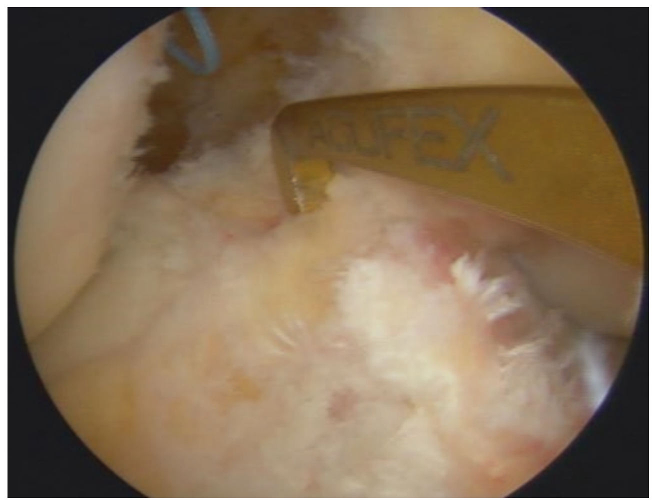

Fig. 6.45 Intra-articular position of the tibial aimer

verified arthroscopically for each pin tunnel in turn (Fig. 6.42) and by the presence of fluid from the cannulated pins (Fig. 6.43).

The ends of a No. 5 nonabsorbable passing suture are inserted into the eyelet of a passing pin which is introduced into the femoral tunnel and brought out of the lateral thigh. The loop of the suture is positioned at the entrance of the femoral tunnel and will be used later in the procedure to pass the hamstring graft (see Fig. 6.45).

Tibial Tunnel

The adjustable tibial aimer is introduced into the knee via the anterior medial portal. It is set between 50° and 55° which produces a sufficiently long tunnel, between 45 and 55 mm length (Fig. 6.44).

The intended intra-articular position of the guide pin is at the level of the posterior edge of the anterior horn of the lateral meniscus and between the medial and lateral tibial eminence (Fig. 6.45). In relation to the PCL, it is situated 7 mm anteriorly, with around 2 mm between the ACL and PCL.

The guidewire is drilled into the joint, and once the position is confirmed as satisfactory, the tunnel is progressively reamed in increments from 5 mm to the final size, which is equal to the measured distal graft diameter (Figs. 6.46 and 6.47). The intra-articular aperture of the tunnel is smoothed with a rasp, and the soft tissue around the external aperture is cleared with an electrocautery pencil and a Cobb periosteal elevator.

Graft Fixation

There are an increasing number of choices of graft fixation, all with their advantages and disadvantages. Healing of hamstring grafts to bone is a long process, and on the femur, we prefer to use a combination of EndoButton CL and Rigidfix cross pins, as they both provide 360° contact between the graft and the bone and have been shown to be effective in resisting slippage under cyclic loading.

Fig. 6.46 The guidewire is drilled into the joint

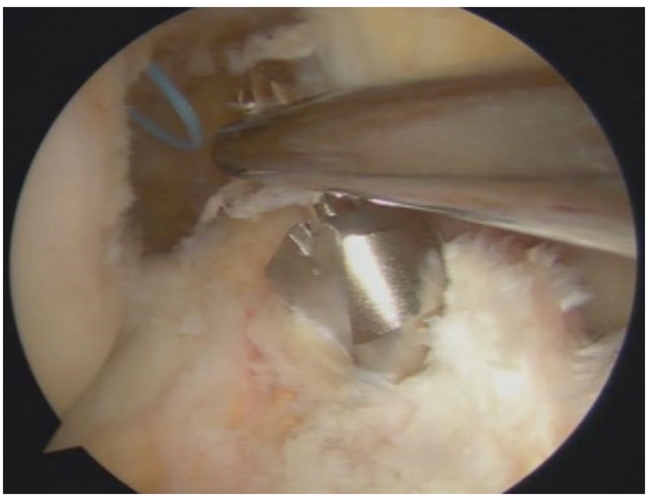

Fig. 6.47 A Kocher holds the guidewire during tibial reaming to prevent it from passing into the joint

The lower bone mineral density of the proximal tibia is the main cause of concern for tibial fixation. The tibial fixation devices must resist shear forces applied parallel to the axis of the tibial bone tunnel. Intratunnel tibial fixation with interference screws seems to demonstrate high initial fixation strength and stiffness with minimal slippage under cyclic loading conditions.

We prefer intratunnel tibial fixation with a bioabsorbable interference screw, but we do not hesitate to add additional cortical fixation with a staple if the fixation does not appear adequate.

Calculation of EndoButton CL Length and Final Graft Preparation

The required EndoButton loop length is decided by subtracting the intended graft length in the tunnel from the total tunnel length. For instance, if the femoral tunnel length measures 48 mm, and 30 mm of graft has been chosen to be inserted into the femoral tunnel, the distance available for the continuous loop is 18 mm. The next shorter loop available will be chosen, to increase the stiffness of the femur-EndoButton CL-TGST graft complex, in this case a 15 mm loop. The pretensioned graft is marked with a surgical marking pen at the measured femoral tunnel length (e.g., 48 mm). 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 which will aid in the removal of the graft if there are any difficulties later in the procedure.

Graft Passage and Femoral Fixation

The loop of No. 5 suture previously placed in the femoral tunnel is retrieved arthroscopically and pulled out of the tibial tunnel. This is used to pass the FiberWire No. 2 flipping suture and other No. 5 passing suture out of 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 passing suture (Fig. 6.48). The previously placed insertion mark guides the passage of the graft 6 mm deeper, to allow the EndoButton to pass outside the lateral femoral cortex and flip. Correct deployment is verified by rocking the EndoButton against the lateral femoral cortex and subsequent tensioning of the graft (Figs. 6.49 and 6.50). When this tension is applied, the previously placed mark at the insertion length will appear at the aperture of the femoral tunnel.

If any doubts exist about secure deployment of the EndoButton, fluoroscopy can be used to check the position of the EndoButton. It should be placed over the cortical bone.

Once the EndoButton is flipped, the two Rigidfix cross pins are introduced from the medial side of the femur. Tension on the graft is maintained during this procedure, at 90° of flexion (Figs. 6.51 and 6.52).

Graft Tensioning

Equal tension is applied to both ends of the six-stranded hamstring tendon graft. The knee is cycled from 0 to 90° for a minimum of 30 cycles to allow the EndoButton CL to settle on the femoral cortex and remove creep from the graft construct. We fix the graft with the knee positioned between 0 and 20° of flexion, ensuring full extension is not limited by the graft isometry.

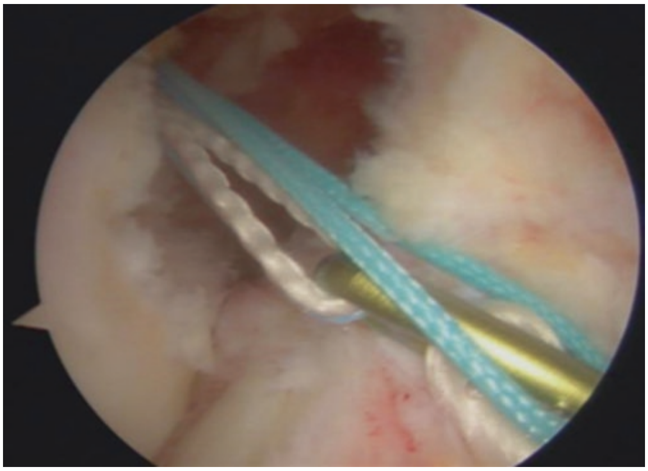

Fig. 6.48 EndoButton and graft passing through tibial and femoral tunnels

Fig. 6.49 Confirming that the EndoButton is flipped

Fig. 6.50 Tension is applied to the graft in order to confirm EndoButton fixation

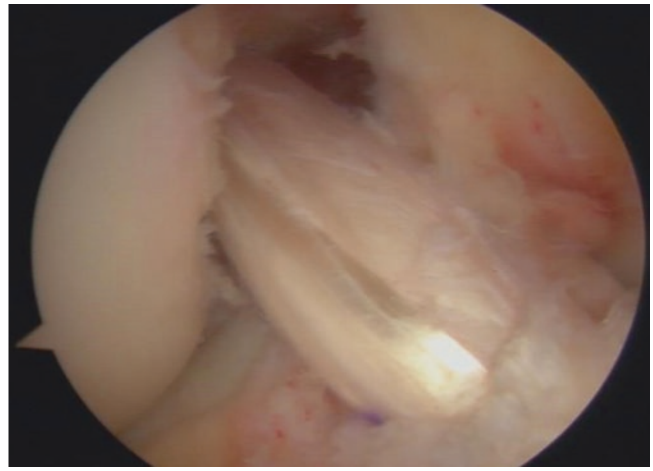

Fig. 6.51 Tension of the graft is confirmed arthroscopically before cross pin fixation

Fig. 6.52 The two Rigidfix cross pins are introduced from the medial side of the femur

Fig. 6.53 A bioabsorbable interference screw for tibial fixation

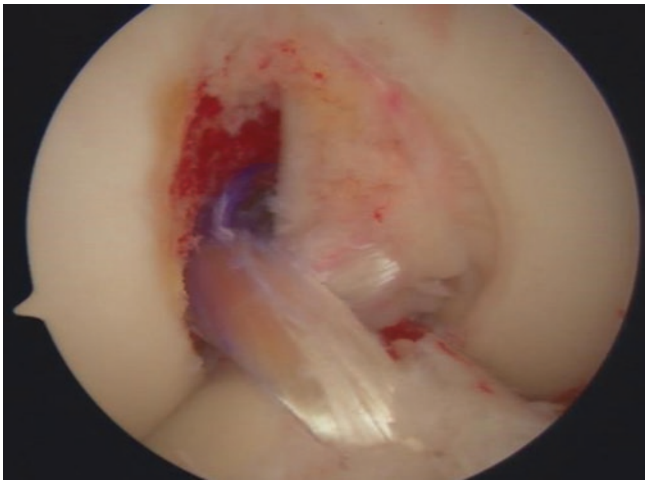

Fig. 6.54 Final assessment of the ACL graft

Tibial Fixation

The bioabsorbable interference screw is our choice for tibial fixation. The direction of the tibial tunnel is identified by passing a 1.1 mm guidewire.

A bioabsorbable screw 1 mm larger than the tibial tunnel diameter is inserted until flush with the cortex (Fig. 6.53). If there was inadequate torque during the insertion of the tapered screw or if the patient has soft bone, supplemental tibial fixation with a soft tissue staple is performed.

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 to the knee, and graft tension and impingement are assessed (Fig. 6.54).

After confirmation that the patient has a full range of motion and negative Lachman, anterior drawer and pivot shift tests, the passing and flipping sutures are cut close to the skin and pulled out of the lateral thigh.

Closure

A closed suction drain is inserted under the sartorius fascia up into the hamstring harvest site to help prevent postoperative hematoma formation and medial ecchymosis. This is removed after 24 h. The sartorius fascia that was preserved during the graft harvest is repaired back to the tibia with a No. 0 absorbable suture. The subcutaneous tissue is closed in layers with fine absorbable sutures.

Postoperative Care

After isolated ACLR full weight-bearing is permitted, a range of motion brace and crutches are supplied, and knee movement is limited to 0–90° for 4 weeks. If there has been a meniscal repair or osteochondral procedure, non-weight-bearing is continued for 4 weeks.

Prophylaxis of thrombosis is by early mobilization, anti-embolism stockings, and a low molecular weight heparin daily for 2 weeks.

The patient is seen at 7–10 days for suture removal and postoperative radiographs.

Complications

The risk of complications such as infection, deep venous thrombosis, and loss of motion are the same as for ACL reconstructions performed with other graft types. 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 strains in the post-operative rehabilitation period.

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 and the semitendinosus is successfully harvested, it is possible in most cases either to triple or quadruple the semitendinosus tendon, depending on its length. 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 polyester tape around a fixation post or an extra-small non-barbed staple. If necessary, this tibial fixation can still be augmented with a 25–30 mm bioabsorbable screw. If the semitendinosus tendon is amputated, it will be necessary to use an alternative autograft (such as the patellar tendon or quadriceps tendon), or allograft tissue (if available and pre-operative consent has been obtained).