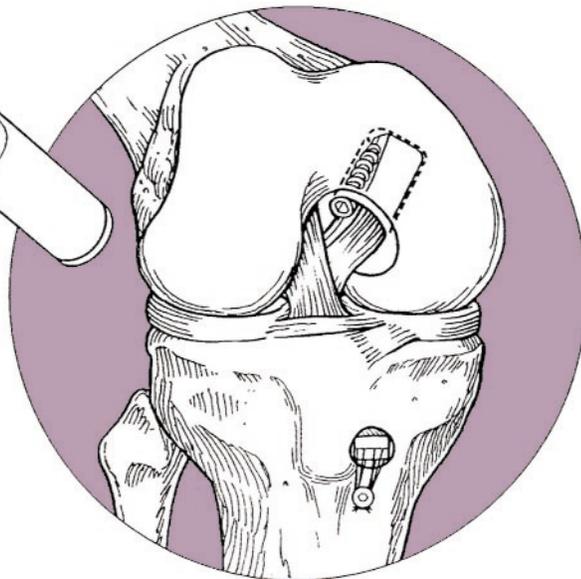
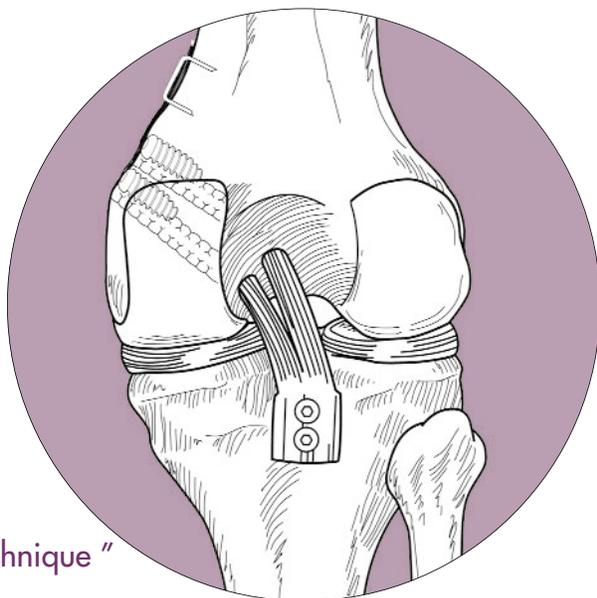


PCL Reconstruction with the Acuflex® Director™ Drill Guide

Featuring Noyes All-Inside and Tibial Inlay
Techniques with a Double-Bundle
Quadriceps Tendon Graft



" All-Inside Arthroscopic Technique "



" Tibial Inlay Technique "

A Smith & Nephew Technique Plus™ Illustrated Guide

PCL Reconstruction with the Acufex® Director™ Drill Guide

As described by Frank R. Noyes, M.D. and Jeffrey D. Harrison, M.D.

This PCL reconstructive system is adaptable to all approaches—including endoscopic, arthroscopically assisted, or open—depending on the experience of the surgeon. The technique includes a unique system of instrumentation previously not available, allowing the surgeon a reproducible technique for PCL reconstruction.

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Introduction

In view of the more advanced arthroscopic skills required for posterior cruciate ligament (PCL) reconstruction, the surgeon is advised to thoroughly review this manual and selected references on PCL indications, contraindications, success rates, graft placement, tensioning, and postoperative rehabilitation.

The successful operative techniques for PCL reconstruction require meticulous attention to the following:

- **Graft harvesting technique**
- **Tibial tunnel technique and placement**
- **Femoral PCL footprint identification**
- **Femoral tunnel placement**

Setup

This procedure begins with the exam under anesthesia to help delineate any subtle instability that may not have been apparent during the office exam. Specific attention is given to palpating the medial tibia-femoral step-off with posterior drawer on the involved and uninvolved knees, later used to confirm restoration of a normal tibiafemoral state after PCL reconstruction. For the All-Inside Arthroscopic Technique, the patient is positioned supine on the operative table. A thigh-high tourniquet is placed over cast padding. An arthroscopic leg holder is then placed on the distal end of the operative table so that flexion of up to 125° can be achieved. The mid portion of the table is slightly flexed, and slight hip flexion is used to prevent stretch of the femoral nerve. The non-operative leg is placed with the hip flexed using a foam leg holder. Ted hose are placed on the non-operative extremity.

For the Tibial Inlay Technique, a lateral decubitus position is used without a leg holder to allow for the open posterior approach.^{2,3}

Arthroscopy of the knee begins with a pressure-sensitive pump. A 0°, 30°, and 70° arthroscope should be available. Routine arthroscopic portals are placed. These include anteromedial, anterolateral, and superolateral portals. During the PCL reconstruction, a transpatellar central portal and posteromedial portal may be necessary. A standard arthroscopic exam of the knee joint is performed, and the PCL rupture is confirmed. Lateral and medial joint opening to varus and valgus stress are documented and measured with the calibrated nerve hook to exclude associated medial or lateral ligament injuries (arthroscopic gap test). Abnormal tibiafemoral joint opening greater than 12 mm to stress testing indicates associated medial or lateral ligament injury requiring reconstruction. Tibiofemoral rotation tests are used to diagnose posterolateral and posteromedial subluxations. In chronic PCL rupture cases, an associated posterolateral reconstruction is frequently required.

Fig. 1a

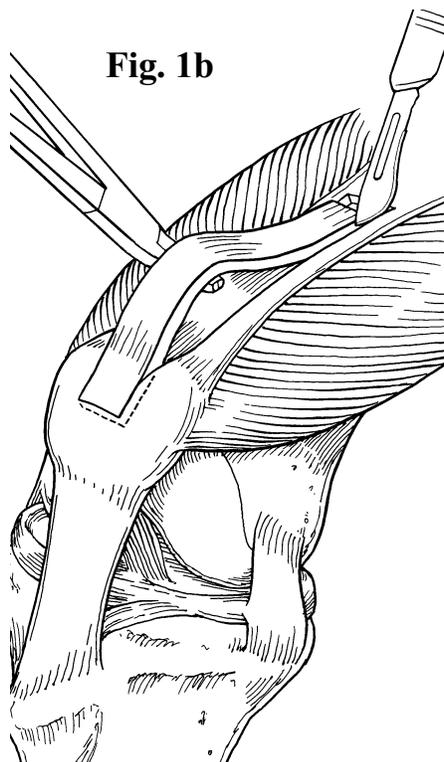
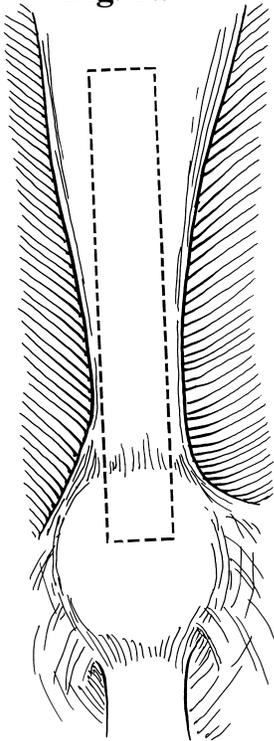


Fig. 1b

Technique: Quadriceps Tendon Harvest

The quadriceps tendon bone graft should be harvested with the knee flexed to 90°. The extremity is exsanguinated, and the tourniquet inflated. A longitudinal incision is made beginning at the superior pole of the patella and extended approximately 5 cm proximally. Dissection is carried sharply through the skin and subcutaneous tissue down through the investing fascia of the thigh. The pre-patellar retinaculum is incised sharply in line with the incision. Care is taken during this step to preserve this tissue for later closure over the proximal patella defect, which will be bone grafted. The paratenon of the quadriceps tendon is incised sharply. The paratenon is dissected off the underlying tendon using dissecting scissors.

The medial margin of the quadriceps tendon and its junction with the vastus medialis obliquus muscle is identified. Leaving a 4 mm margin of tendon medially, the tendon is incised sharply in line with its fibers. Care is taken to stay parallel with the tendon fibers, which are in line with the anatomical axis of the femur. The tendon is incised through all three layers down to the synovium, which has a bluish color during the dissection. Care should be taken not to enter the synovium—if, however, the synovium is entered, this is not detrimental and a watertight closure prior to further arthroscopy will not hamper further procedures. Beginning at the superior pole of the patella 12 mm lateral to the medial incision, the tendon is again incised in line with its fibers. The overall length of the graft is approximately 110 mm. If additional length is required from the graft, the superficial

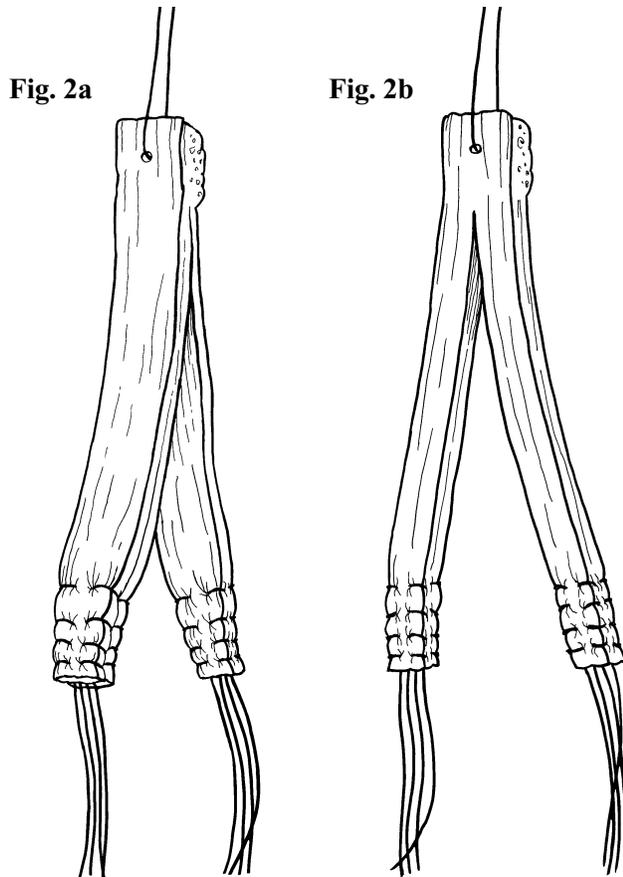
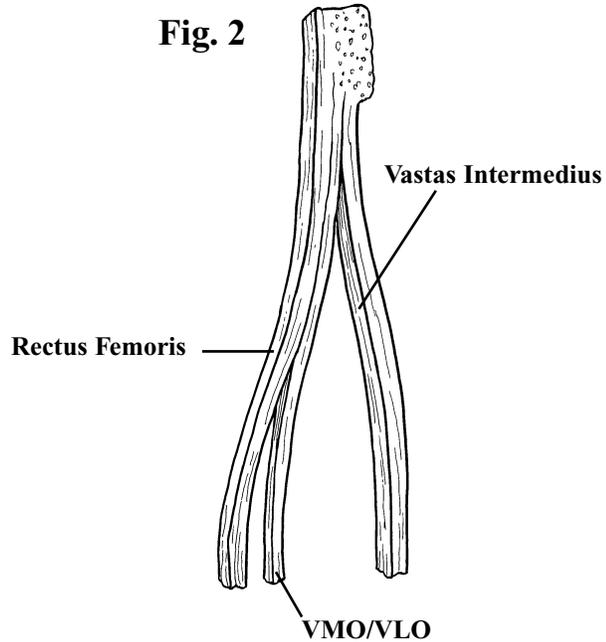
muscle fibers of the vastus lateralis can be elevated sharply off of the rectus tendon, and the additional length of the tendon can be harvested.

Curved Mayo scissors are then placed bluntly between the quadriceps tendon and the underlying synovial layer. The plane between the tendon and the synovium is developed. The proximal end of the tendon is transected. The proximal end of the graft is grasped with a sponge and is pulled anteriorly. The combined quadriceps tendon is approximately 10 mm in anterior-posterior width. A knife is used to release the inferior synovium to the tendon down to the superior pole of the patella.

A No. 10 blade is used to cut a 12 mm wide x 22 mm long patellar bone graft (Figs. 1a and 1b). A powered saw is then used with a 10 mm wide blade that has been previously marked with a steri-strip, 8 mm from its cutting teeth. The anterior cortex of the patella is then cut at an angle of 20° to the sagittal plane to a depth of 7–8 mm, with a length of 22 mm and a width of 12 mm. The quadriceps tendon is reflected anteriorly, and the saw is used to cut the superior pole of the patella in the coronal plane. A 1/4-inch curved osteotome is then placed in the distal cut on the anterior cortex of the patella, and with the slight tap of a mallet, the bone block is easily removed. The patellar bone portion of the PCL graft may be placed in the femoral side or alternatively on the tibia (Inlay Technique), depending on which surgical option is elected.

Graft Preparation

The quadriceps tendon is composed of three layers forming the insertion of the four quadriceps muscles. The anterior-most layer represents the rectus femoris tendon; the middle layer represents the confluent vastus medialis and the vastus lateralis tendons; and the posterior layer represents the vastus intermedius tendon (Fig. 2). The two anterior layers are sutured together to form one bundle, and the posterior layer is sutured as a separate bundle, to form the split quadriceps-tendon two-bundle graft (Fig. 2a). An alternative graft preparation technique for the Tibial Inlay procedure is to split the graft sagittally (Fig. 2b). Careful dissection of the two bundles to within 10 mm of the bone is required. Each bundle of the graft is carefully sutured with three #2 non-absorbable sutures with a whip stitch, using three throws on each corner of the tendon graft. Two #2 non-absorbable sutures are placed through the 1/16-inch patellar drill hole and clamped on their loose ends. The graft bone block is sized to fit in the Acufex PCL Dilator Graft Sizer. The overall length of the graft is approximately 110 mm.



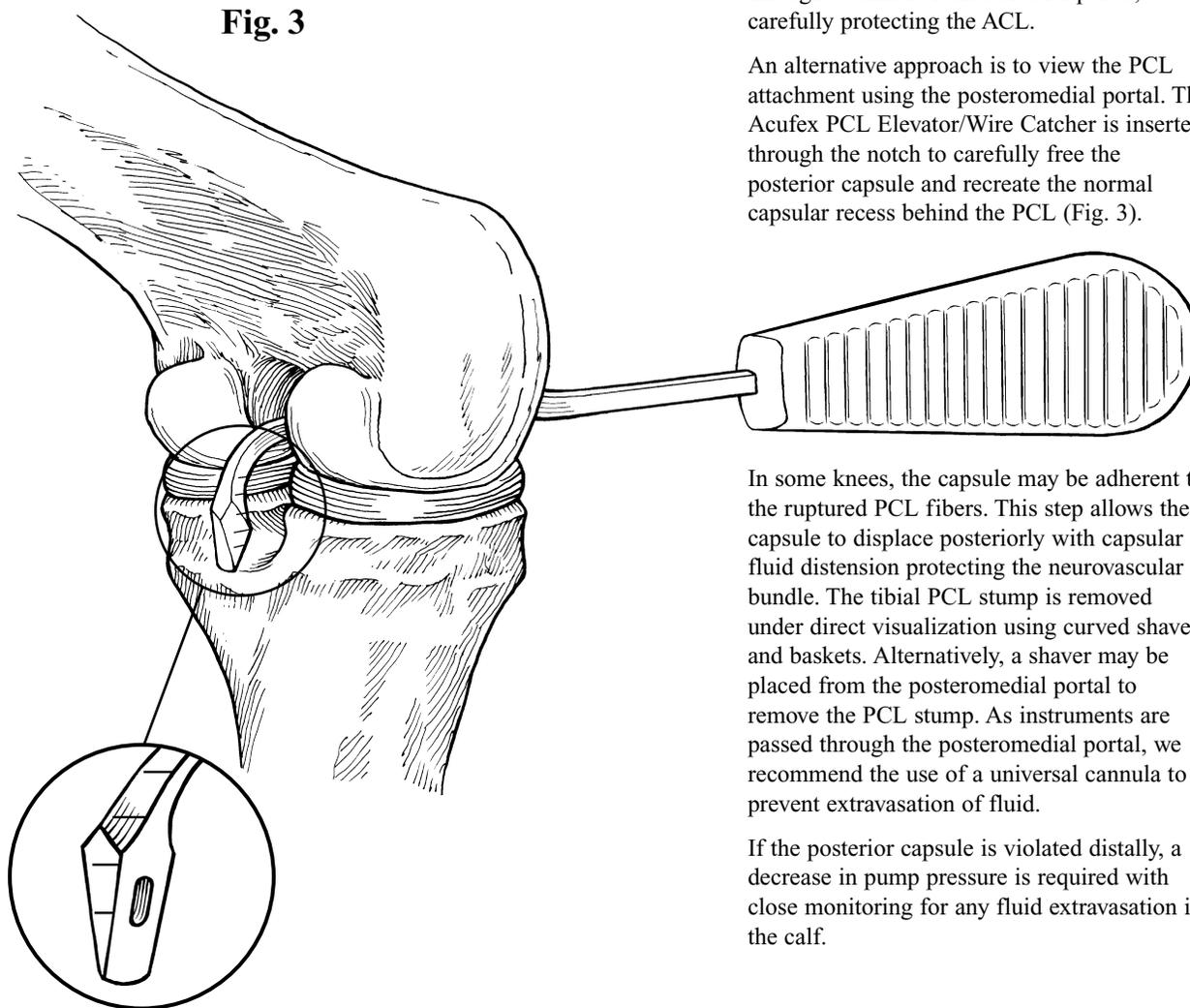
Coronal Split
Shallow-Deep
Femoral Orientation
 (See Fig. 14)

Sagittal Split
Shallow-Shallow
Femoral Orientation
 (See Fig. 7)

Tibial Preparation

An arthroscope (30° or 70°) is placed through the anteromedial portal. The scope is placed high up in the notch to view the posterior region of the joint. Instruments are placed through a central or anterolateral portal, carefully protecting the ACL.

An alternative approach is to view the PCL attachment using the posteromedial portal. The Acufex PCL Elevator/Wire Catcher is inserted through the notch to carefully free the posterior capsule and recreate the normal capsular recess behind the PCL (Fig. 3).



In some knees, the capsule may be adherent to the ruptured PCL fibers. This step allows the capsule to displace posteriorly with capsular fluid distension protecting the neurovascular bundle. The tibial PCL stump is removed under direct visualization using curved shavers and baskets. Alternatively, a shaver may be placed from the posteromedial portal to remove the PCL stump. As instruments are passed through the posteromedial portal, we recommend the use of a universal cannula to prevent extravasation of fluid.

If the posterior capsule is violated distally, a decrease in pump pressure is required with close monitoring for any fluid extravasation in the calf.

Location of the Tibial Tunnel

Our preferred location is just medial to the tibial tuberosity (Figs. 4a and 4b).

A 2.5 cm skin incision is placed approximately 3–4 cm distal to the joint line, just medial to the tibial tuberosity.

We prefer the tunnel position at approximately a 50° angle to the tibia (Fig. 4).

Drilling of the Tibial Tunnel (All-Inside Technique)

The Acufex Director PCL Tibial Aimer is placed through the anteromedial portal onto the posterior cortex of the tibia. The tip of the guide rests on the posterior capsule insertion, with the target 5 mm proximal to the posterior slope of the tibial metaphysis within the PCL footprint (Fig. 4c). This ensures that there is sufficient tibial bone proximal to the tunnel to prevent migration of the graft tunnel in a proximal direction after reconstruction. The desired angle of the guide is chosen and the black locking knob is tightened.

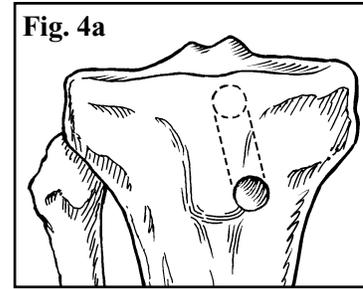


Fig. 4a
Anterior View:
Location of Tibial Tunnel

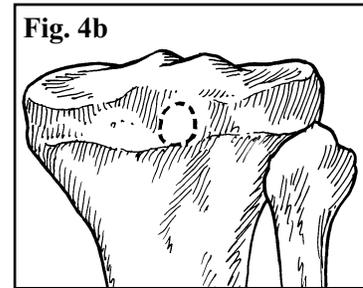


Fig. 4b
Posterior View:
Location of Tibial Tunnel

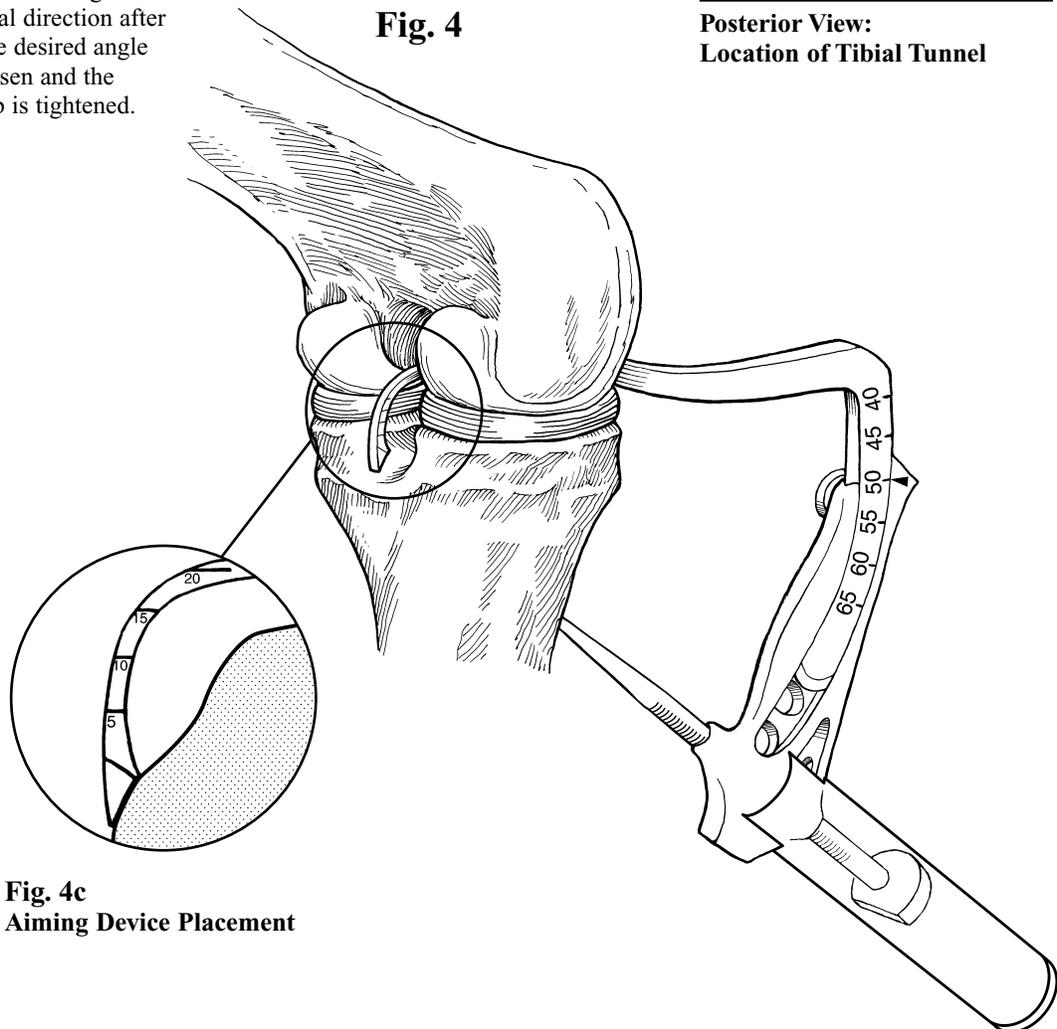
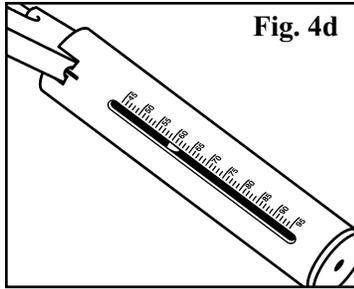
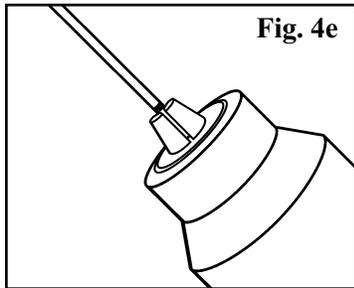


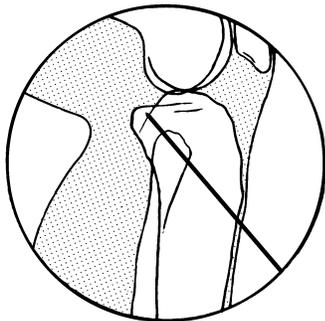
Fig. 4c
Aiming Device Placement



Acufex® Director™ PCL Safety Stop



Chuck to Laser Mark on Guide Wire



**Fig. 4f
Fluoroscopic Tibial
Guide Wire Placement**

The ratcheting bullet is advanced to hold the drill guide in place. The Acufex Director PCL Safety Stop (Fig. 4d) is then attached to the Acufex Director Drill Guide by lining the recessed prongs of the safety stop with the hole of the handle above the bullet slide. The Acufex PCL Safety Guide Wire is chucked on the power drill to the laser mark on the guide wire (Fig. 4e). This is very important since all measurements are made off of this point. This prevents the guide wire from being advanced beyond the aiming device on the posterior tibial cortex. The guide wire is drilled with the knee flexed at 90°. Fluoroscopy may be used to verify guide wire placement (Fig. 4f). The Acufex PCL Elevator/Wire Catcher is placed over the guide wire, exiting the posterior cortex of the tibia (Fig. 5).

The tunnel is drilled to the desired diameter, typically 10 or 11 mm based on the measured graft width. This is accomplished by drilling the tunnel under power, up until the point at which the posterior cortex is encountered. The drill is taken off power, and a hand chuck is placed on the drill bit. The remaining posterior cortex is then drilled by hand.

An alternative to the above tunnel-drilling sequence is to use a coring reamer to harvest a tibial metaphyseal bone plug, used for grafting the patellar bone defect.

There are two safety procedures built into the technique to protect the posterior neurovascular structures. The Acufex PCL Elevator/Wire Catcher has a wide shape with a central recess 5 mm up from its tip to engage the tibial guide wire just proximal to the capsular insertion at the PCL tibial footprint. The specifically designed Acufex Director PCL Safety Stop always controls the depth of the guide wire in the tibia, irrespective of the angle or position of the PCL tibial aimer.

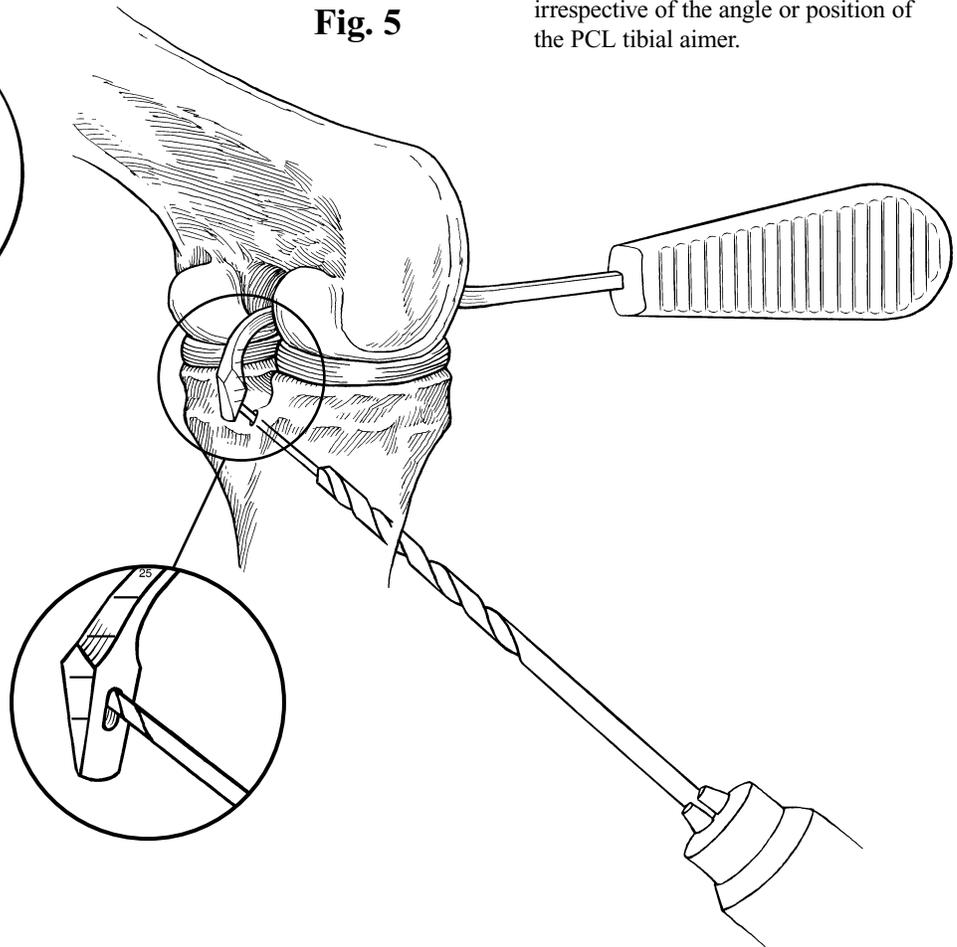
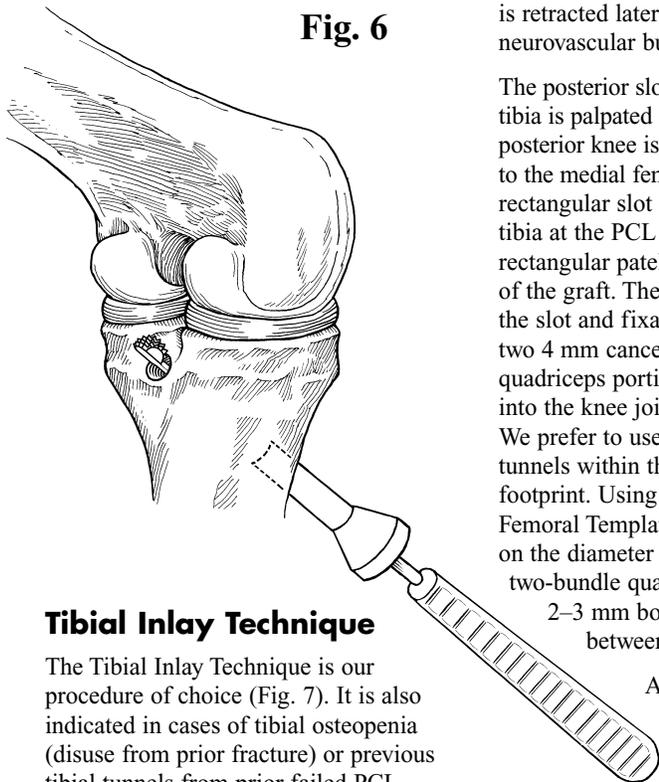


Fig. 5

Chamfering of the Tibial Tunnel

The anterior edge of the tunnel is carefully chamfered by hand with a rasp to prevent graft abrasion (Fig. 6). The remaining PCL stump is removed so that the graft will lie flat against the tibia. It is ideal to have 12–15 mm of bone retained above the PCL footprint to prevent the graft from cutting through the tibia (windshield wiper effect). This would produce widening of the tibial tunnel and graft laxity.

Fig. 6



Tibial Inlay Technique

The Tibial Inlay Technique is our procedure of choice (Fig. 7). It is also indicated in cases of tibial osteopenia (disuse from prior fracture) or previous tibial tunnels from prior failed PCL surgery. The bone portion of the graft is fixed to the posterior tibia, which prevents the collagenous portion of the graft from cutting through the posterior tibia or from the presence of a sharp angulation of the graft when a tibial hole is used. Patient positioning is critical to the success of this procedure. The best option is the lateral decubitus with the hip flexed, abducted and externally rotated.² The patient is positioned in a “bean bag” to allow rotation of the table for the arthroscopic procedure.

A longitudinal incision beginning 2 cm proximal to the flexion crease of the knee is carried distally over the medial head of the gastrocnemius and lateral border of the semi-membranous tendon. The dissection is carried down sharply through the skin and subcutaneous tissues. The medial border of the gastrocnemius tendon is identified. The dissection is carried out between the gastrocnemius and semi-membranous muscle bellies. The medial head of the gastrocnemius may be partially released off the distal femur to obtain additional exposure. The gastrocnemius is retracted laterally, protecting the neurovascular bundle.

The posterior slope of the proximal tibia is palpated and the capsule of the posterior knee is incised sharply, adjacent to the medial femoral condyle. A rectangular slot is cut into the proximal tibia at the PCL insertion to fixate the rectangular patella bone block portion of the graft. The bone is recessed into the slot and fixation is achieved with two 4 mm cancellous screws. The quadriceps portion of the graft is passed into the knee joint with a suture passer. We prefer to use two separate bony tunnels within the anatomic PCL footprint. Using the Acufex PCL Femoral Template (Fig. 9a) and based on the diameter of each arm of the two-bundle quadriceps tendon graft, a 2–3 mm bony bridge is maintained between the femoral tunnels.

A vastus medialis muscle splitting extra-articular approach is used to place two guide wires at the one o'clock and three o'clock position (Figs. 7a and 12) within the PCL anatomic attachment site using the Acufex PCL Femoral Template (Fig. 9a). Note: An additional 2–3 mm of separation between the guide wires is required for the two-tunnel technique. This is performed by placing the posterior guide wire 2 mm more posterior than that shown in Fig. 9a.

RCI or BioRCI soft tissue interference screws plus suture and femoral fixation post are used for secure fixation.

Fig. 7

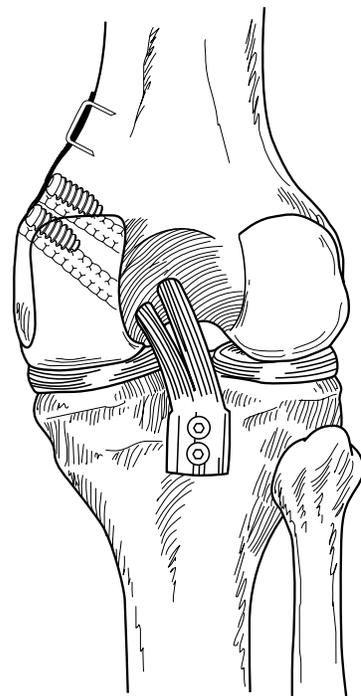
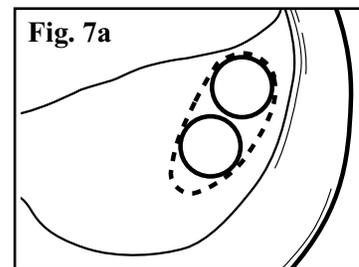


Fig. 7a



Femoral Tunnel Location

The key to femoral tunnel positioning is having a clear understanding of the native PCL anatomy and determining

what portion of the PCL will be reconstructed. We recommend anatomic reconstruction of the PCL. The graft is placed entirely within the PCL footprint. We have previously defined the terminology of the PCL graft position on the medial femoral condyle²¹ (Fig. 8). The terms “high,” “low,” “shallow,” and “deep,” are used with the knee at 90° knee flexion. The terms “anterior,” “posterior,” “proximal,” and “distal,” relate to the

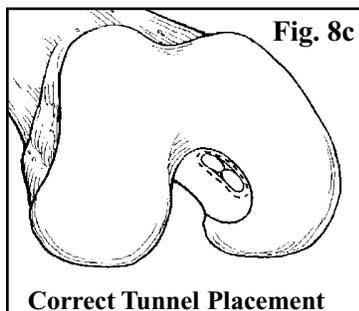
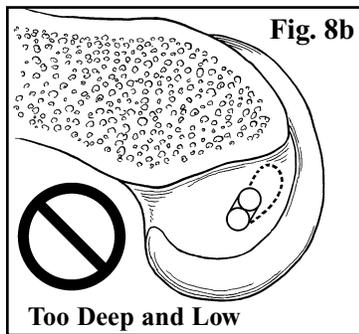
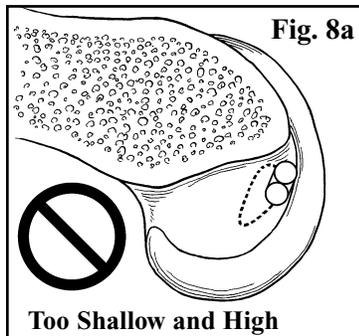
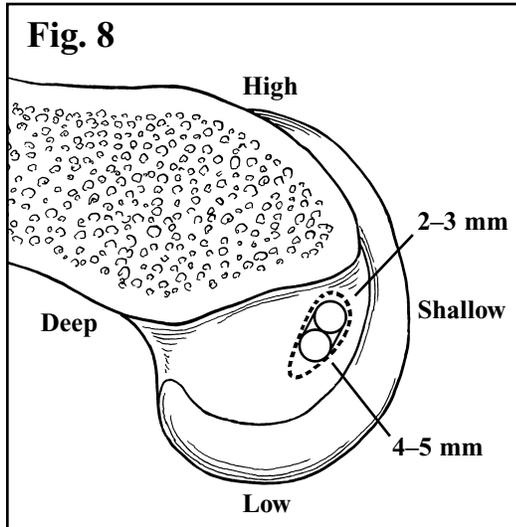
anatomic position at full extension. The native PCL insertion is elliptical and extends from high in the notch (twelve o'clock) along the lateral aspect of the medial femoral condyle, to approximately five o'clock, occupying the distal one-third of the femoral condyle (see 8d and 8e, PCL footprint photographs). The footprint extends high in the roof of the notch and then, in its shallow position, follows the articular cartilage within 2–3 mm of its edge, until at the five o'clock position, the footprint is 5 mm from the edge. The deep portion of the footprint is 11–12 mm from the articular cartilage high in the notch.

The native PCL is a non-isometric structure. Our biomechanical data on possible sites for femoral placement show one ideal position is high to replace roof PCL fibers, and low to replace fibers on the condylar wall, maintaining all fibers within the PCL footprint (Fig. 7a). This position provides optimal control to posterior subluxation without subjecting the graft to extraordinarily high forces. We recommend a drill point at the one o'clock and three o'clock position (right knee, Fig. 7a, Tibial Inlay Technique).

The second PCL graft position is that for the All-Inside Technique where the patellar bone is placed in a femoral oval tunnel (Fig. 11). This graft position reproduces distal and proximal portions of the PCL to allow reciprocal loading between both graft bundles with knee flexion.

The PCL footprint is mapped out with a calibrated probe. The shallow and deep portions, and high and low portions, are identified. The PCL footprint is outlined with a Bovie electrocautery. This prevents the surgeon from committing the common error of placing the graft too deep in the notch.

Caution: If the graft is placed too shallow and high, the graft will see high tensile forces with knee flexion, and the joint will be over constrained (Fig. 8a). If the graft is placed too deep and low, it will slacken with knee flexion and fail to prevent posterior tibial subluxation (Fig. 8b). Figure 8c shows correct tunnel placement.



8d. PCL Footprint—Side View



8e. PCL Footprint—Oblique View

All-Inside Femoral Tunnel

The Acufex PCL Femoral Template is placed through the anterior medial portal with the arthroscope in the anterolateral portal. The Acufex PCL Femoral Template will define the position of either two 7 mm holes for a 9 x 13 mm oval tunnel or two 8 mm holes for a 9 x 14 mm oval tunnel on the femoral condyle (Fig. 9a). The top edge of the template should be placed 2 mm from the articular margin. With either guide, the 4 mm laser mark on the shaft should be placed on the articular margin (Fig. 9b). This places the high portion of the tunnel within 2–3 mm from the articular cartilage margin and the low portion of the tunnel within 4–5 mm from the articular cartilage margin. A Bovie electrocautery is used to mark the desired starting holes. A small marking curette is used to make pilot holes in the medial femoral condyle. Through a lateral portal, a 2.4 mm drill tip guide wire is placed through the high slot in the aiming device and drilled through the medial femoral condyle (Fig. 9). The second drill tip guide wire is placed in the low slot and again drilled parallel to the first wire through the medial femoral condyle. The anterior lateral portal is extended to a 2 cm mini-arthrotomy. The guide wires are then over-reamed with an endoscopic drill to 8 mm, forming an oblong tunnel (Fig. 10). Care must be taken to avoid the cartilage of the lateral femoral condyle with the reamer. The central bone bridge

and walls are fashioned as necessary. The Acufex PCL Dilator gently conforms the femoral elliptical footprint to 9 x 13 mm without impacting the condyle and producing a fracture (Fig. 11). The opening in the Acufex PCL Dilator handle is 9 x 13 mm to help in sizing the bone block.

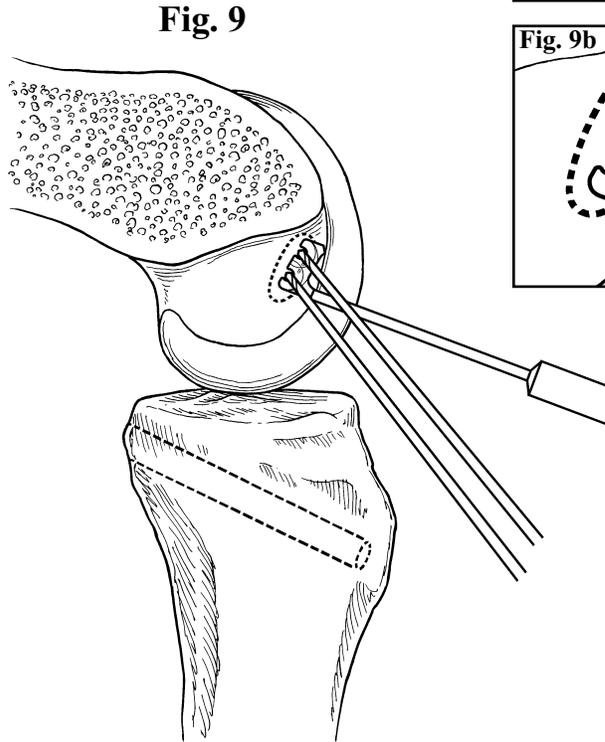


Fig. 9

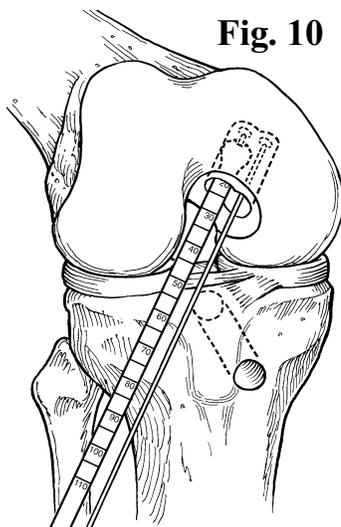
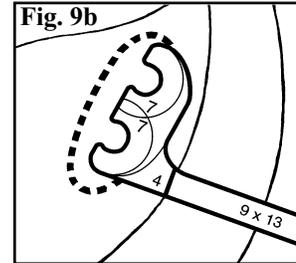
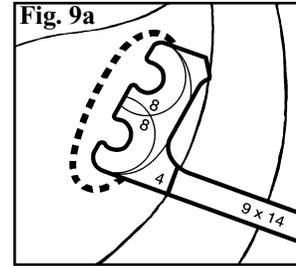


Fig. 10

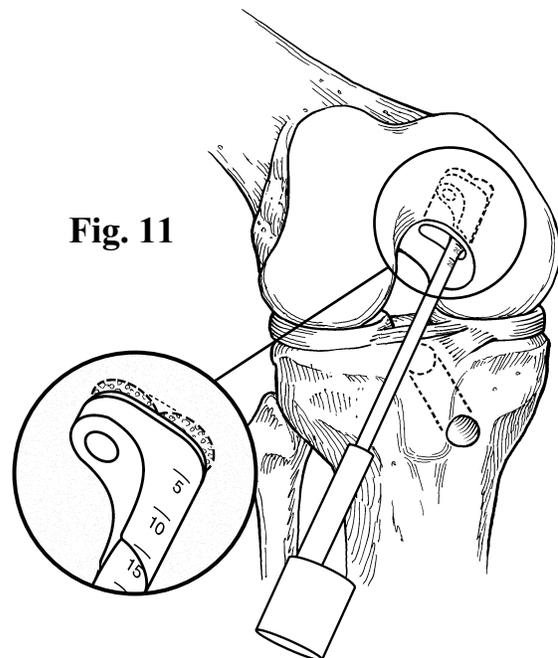


Fig. 11

Outside-In Femoral Tunnel

After locating the desired position of the femoral tunnel (as described previously), the Acufex Director PCL Femoral Aimer is placed through the anteromedial portal, and desired femoral tunnel position is located (Fig. 12). Using the prior longitudinal quadriceps graft incision, the vastus medialis is exposed and a muscle splitting incision is made in-line with its fibers. An extra-articular subperiosteal dissection is performed to expose the anteromedial femur. A guide wire is then placed through the femoral aimer into the knee joint. Externally, the 2.4 mm guide wire enters the medial femoral condyle midway between the articular cartilage margin and the femoral epicondyle. This leaves a sufficient bony bridge to prevent inadvertent femoral condyle fracture or future osseous necrosis of the medial femoral condyle. A second guide wire is then placed using the drill guide (3–9 offset guide). This approach may be used for either the Tibial Inlay Technique or for the femoral placement of the patellar bone portion of the graft.

Alternatively, if a single tunnel is desired, a point 8 mm deep to the articular cartilage is chosen. The Acufex Director PCL Femoral Aimer is used as described above. The guide wire is then over-reamed to the desired size of the tunnel.

Fig. 12

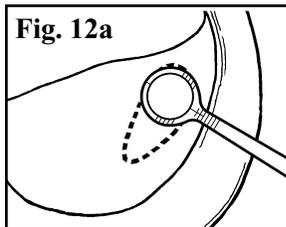
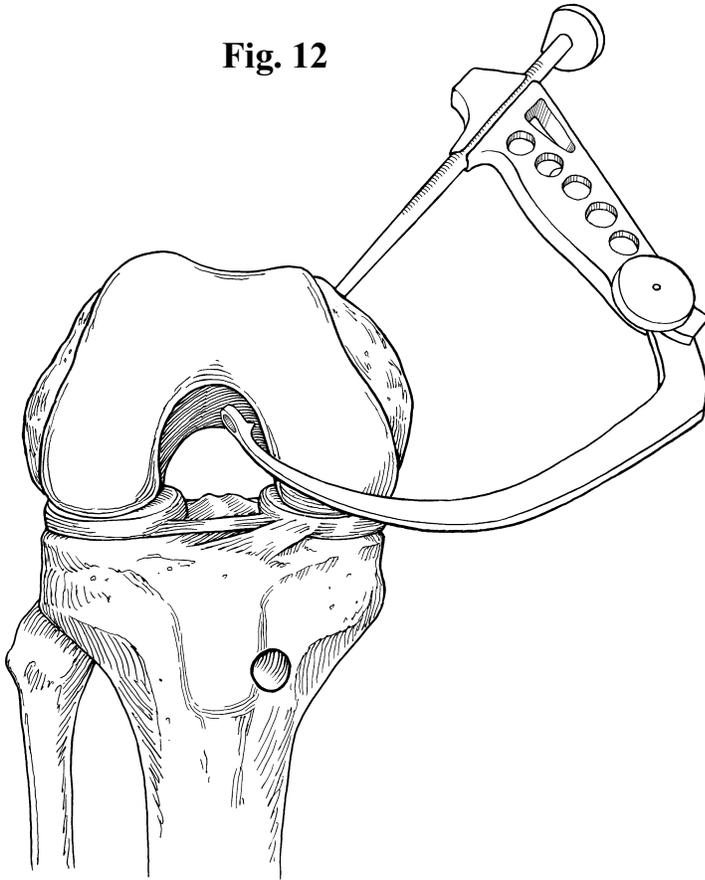


Fig. 12a
Placement of First Guide Wire

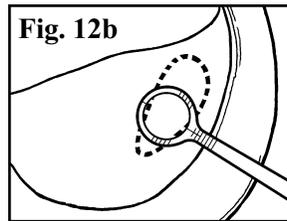


Fig. 12b
Placement of Second Guide Wire

All-Inside Graft Passage

A 20-gauge wire is then passed through the tibial tunnel and grasped anteriorly with a grasper or nerve hook through the antero-lateral arthrotomy (Fig. 13). The soft tissue ends of the quadriceps tendon graft are then passed through the lateral arthrotomy and intra-articularly into the tibial tunnel (Fig. 14). If difficulty is encountered in entering the tibial hole, a switching stick through the posteromedial portal makes an excellent pulley to help pull the soft tissue end of the graft around the posterior aspect of the tibia. Alternatively, the Acufex PCL “Shoehorn” can be used to pass the graft around the posterior tibial lip. The shallow bundle is marked with ink and a distal lateral orientation maintained. The deep portion is in a proximal medial orientation as it passes into the tibia.

The bone block is threaded with two #2 monofilament absorbable sutures that are placed into a passing pin. The pin is then passed through the anterolateral arthrotomy into the tunnel in the medial femoral condyle (Fig. 14).

The bone block is then passed into the femoral tunnel. Either through the arthroscope or mini-antrolateral portal, the bone block is carefully oriented into the correct position. The cancellous surface is oriented deep in the tunnel, and the tendinous portion is shallow in the tunnel (Figs. 15a and 15b).

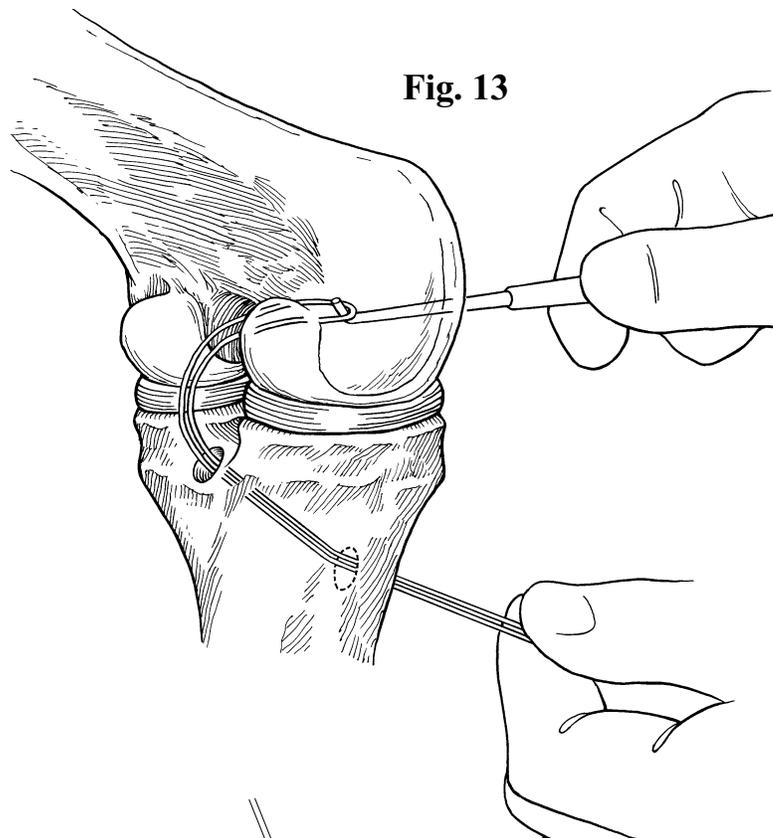


Fig. 13

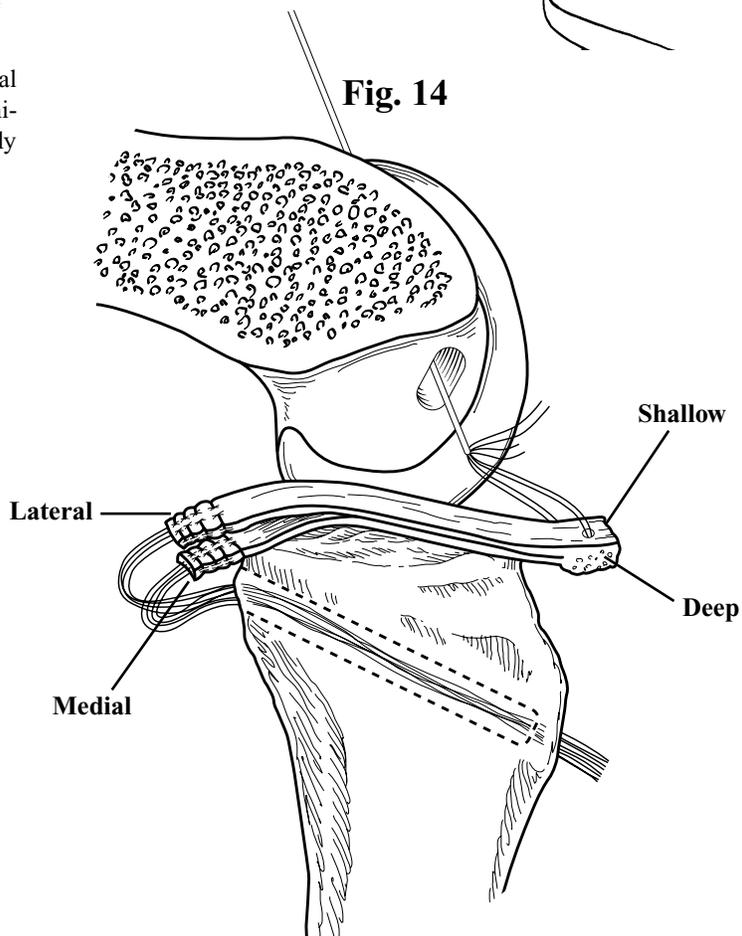
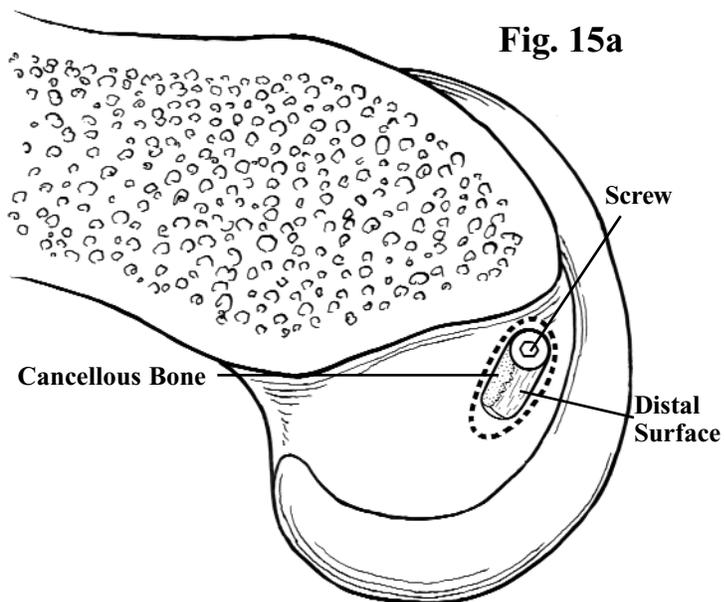
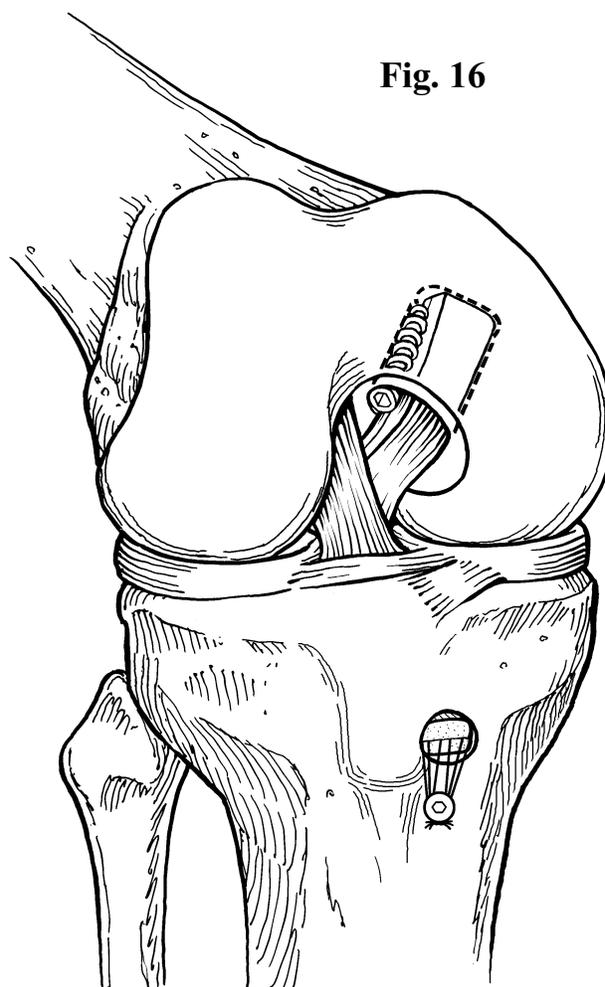
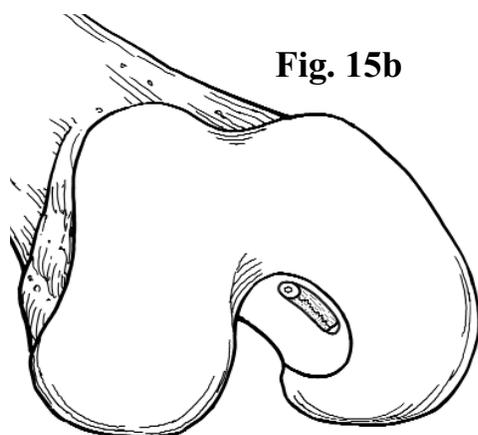


Fig. 14



Femoral Fixation

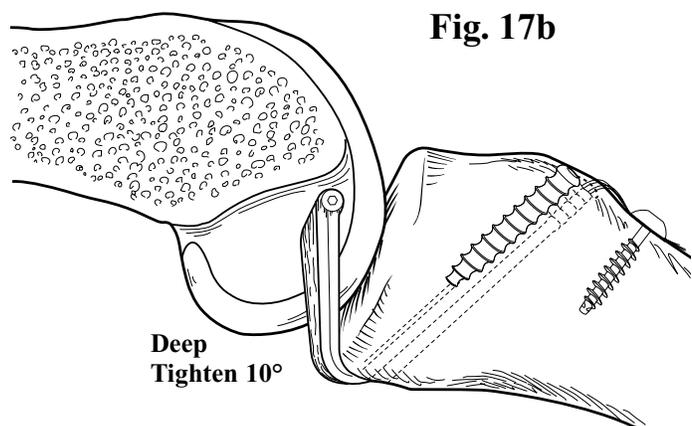
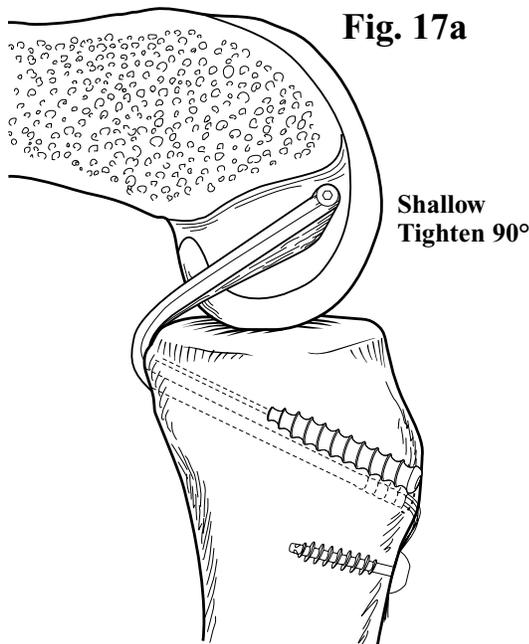
The bone block is secured with a 7 x 20 mm interference screw in the high side of the tunnel from either the anterolateral portal in the All-Inside Technique or superomedial incision in the Outside-In Technique (Fig. 16).



Graft Tensioning and Tibial Fixation

The knee is then taken through a full range of motion and cycled multiple times, conditioning the graft. A 2.4 mm drill hole is then placed 1 cm distal to the inferior border of the tibial tunnel. An Acufex Fixation Post is then placed in the anterior tibia through the drill hole (Figs. 17a and 17b). The knee is flexed 90°, and the tibial femoral step-off is palpated, ensuring restoration of normal tibial femoral position (step-off) and obliteration of the posterior drawer. The knee can be further flexed to 120° to verify that the joint is not over-constrained. A 10-pound anterior drawer

is placed on the leg with a 10-pound tensile force on the sutures. The distal two-thirds of the graft, which is in the more shallow femoral position, is then tensioned at 90° flexion and tied over the post (Fig. 17a). The knee is then extended to 10° flexion with a 10 lb. tensile load. The sutures of the deep femoral positioned graft are then tied over the post (Fig. 17b). Alternatively, if a one-bundle graft is chosen or if a two-bundle graft is placed through two separate femoral tunnels, the graft bundle(s) are tensioned at 90° of flexion. RCI or BioRCI soft tissue interference screw fixation is added for fixation strength.



Postoperative Care

Distal pulses and color need to be documented at the end of the case. The extremity should be elevated for the following 72 hours. The knee is immediately placed into a compression dressing with a cooling device and a hinged knee brace. The brace is worn in full extension for the first four weeks for added graft protection. The limb is never positioned where an active or passive posterior tibial force or a tibial gravity position could occur, which could excessively load the PCL graft. Active quadriceps knee motion exercises from 90° to 0° are begun immediately postoperatively. Knee flexion is limited by an adjustable hinge brace and gradually progressed to 110° by four weeks, 120° at six weeks, and 135° by eight weeks. Patients are allowed toe-touch weight-bearing only until quadriceps control is obtained. One-quarter weight-bearing with the knee in extension is allowed at two weeks and then gradually progressed to full by six weeks. Exercises and therapy modalities are begun immediately postoperatively and include patellar mobilization, electrical muscle stimulation, cryotherapy, flexibility, isometrics, and supine leg raises. Once partial weight-bearing is allowed, closed kinetic chain exercises are begun and include low flexion angle wall-sitting and mini-squatting. During this time, balance and

proprioceptive training are also initiated. Open kinetic chain exercises using weight machines are implemented at varying time periods during the program. Knee extension in the 90° to 0° range is begun at the second week, leg press exercises in the 50° to 0° range and hip adduction exercises are allowed at the third to fourth week, and knee flexion hamstring curls are begun at the sixteenth week. We emphasize patellofemoral protection and a gradual progression of weight exercise machines to avoid high pressure if there is any damage to the patellofemoral joint. Conditioning exercises are begun as early as the first post-operative week with an upper extremity ergometer and progress to stationary bicycling at the third to fourth week. An aquatic program is begun at the twelfth week. Running and sports-specific training are delayed for at least six months and are initiated when the patient demonstrates 70% of the quadriceps and hamstring's strength on isokinetic testing. Objective measurement of anterior-posterior tibial displacement (30 pounds, 134 N) at 30° of knee flexion, and stress radiography of posterior tibial subluxation,¹⁵ are performed postoperatively at routine intervals.

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