Technical Note

Anatomic Double-Bundle Posterior Cruciate Ligament Reconstruction Using Hamstring Tendons

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Abstract: Recent biomechanical studies have shown that an anatomic double-bundle posterior cruciate ligament (PCL) reconstruction is superior in restoring normal knee laxity compared with the conventional single-bundle isometric reconstruction. We describe a modification of an endoscopic PCL reconstruction technique using a double-bundle Y-shaped hamstring tendon graft. A double- or triple-bundle semitendinosus-gracilis tendon graft is used and directly fixed with soft threaded biodegradable interference screws. In the medial femoral condyle, 2 femoral tunnels are created inside-out through a low anterolateral arthroscopic portal. First, in 80° of flexion, the double-stranded gracilis graft is fixed with an interference screw inside the lower femoral socket, representing the insertion site of the posteromedial bundle. In full extension the combined semitendinosus-gracilis graft is pretensioned and fixed inside the posterior aspect of the single tibial tunnel. The double- or triple-stranded semitendinosus tendon is inserted in the higher femoral tunnel, presenting the insertion site of the anterolateral bundle. Finally, pretension is applied to the semitendinosus bundle in 70° of flexion and a third screw is inserted. Using this technique, the stronger semitendinosus part of the double-bundle graft, which mimics the anterolateral bundle of the PCL, is fixed in flexion, whereas the smaller gracilis tendon part (posteromedial bundle) is fixed in full extension. Thus, a fully arthroscopic anatomic PCL reconstruction technique is available that may better restore normal knee kinematics as compared to the single-stranded isometric reconstruction. **Key Words:** Posterior cruciate ligament—Double bundle—Biodegradable interference screw—Hamstring tendon.

Until recently, the main interest in knee ligament surgery has been the treatment of the more often injured anterior cruciate ligament (ACL). Lately there seems to be less controversy about its surgical treatment and, hence, in recent years more and more attention has been directed toward clinical and biomechanical investigations of the surgical reconstruction of the posterior cruciate ligament (PCL).[1,2] Today, the most common method of surgical replacement of an insufficient PCL involves the patient's own patellar tendon.[3-6] Because there is always some degree of donor-site morbidity associated with harvest of the middle-third patellar tendon,[7,8] there has recently been a trend to prefer the use of hamstring tendons for the replacement of the ACL as well as for the PCL.[9-15]

Traditionally, hamstring tendons grafts are fixed extracortically, away from the original cruciate ligament insertion site,[16-18] thus resulting in a reduced construct stiffness and a possible construct stretch out.[19-22] Recently, a technique for the replacement of the PCL by a single bundle of 4 hamstring tendon strands and direct tendon-to-bone fixation using metallic interference screws was described.[13] Experimental and clinical studies support the fast healing of tendon-to-bone fixation using interference screws.[23,24]

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In conventional single-bundle PCL reconstruction, it is recommended that femoral graft fixation be placed in the so-called most isometric point.[25-27] However, the normal PCL consists of a posteromedial bundle that is tight in extension, and a stronger anterolateral bundle that is mostly taught in flexion.[28,29] Recent reports have demonstrated the biomechanical superiority of a double-bundle versus a single-bundle PCL reconstruction in restoring normal knee laxity.[30,31] Thus, a double-bundle reconstruction of the PCL mimics more closely the natural behavior of the normal PCL and could therefore restore normal knee laxity across the full range of motion.

To improve the surgical technique of PCL reconstruction, the following endoscopic double-bundle technique and a simple method of posterolateral stabilization with direct tendon-to-bone fixation using biodegradable interference screws has been developed.

SURGICAL TECHNIQUE

Arthroscopy Portals

The first arthroscopy portal is a standard high anterolateral portal used for the arthroscope. An additional working portal lies lateral just above the joint line.[32] The third portal lies medial to the patellar tendon just above the tibial plateau (Fig 1). A posteromedial portal is later created under direct arthroscopic vision.

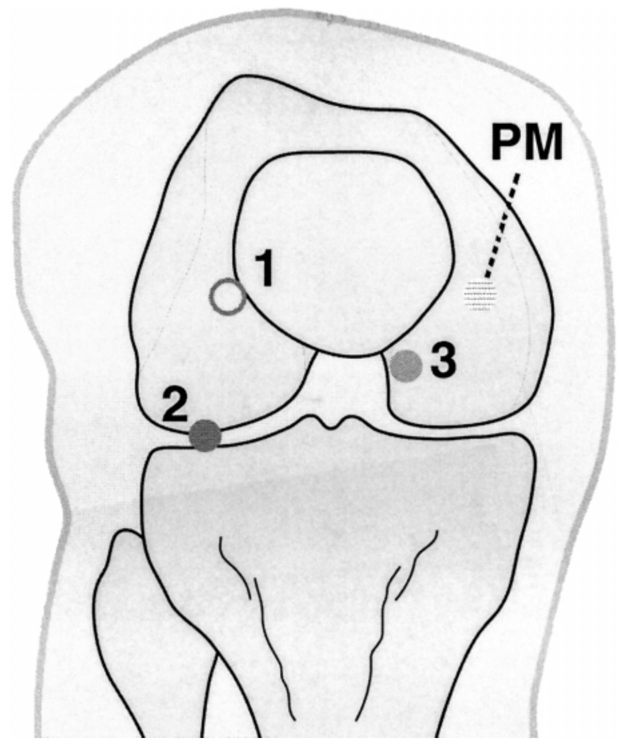


Figure 1. The arthroscopy portals and skin incisions are marked on the skin with a marking pen (1, high anterolateral arthroscope portal; 2, low anterolateral working portal; 3, medial working portal; PM, posteromedial portal).

Graft Harvest and Preparation

The hamstring tendons are harvested through an oblique 3-cm long skin incision along Langer's lines. The semitendinosus tendon is delivered from the posterior aspect of the incision using a tendon hook and is pulled out of the wound after transecting all strands to the gastrocnemius muscle. While the tendons stay attached at their tibial insertion, an open-ended tendon stripper is used for the proximal transection. The second tendon is delivered and transected in the same way.

Each tendon is doubled over a large nonabsorbable holding suture (white suture for the semitendinosus and colored for the gracilis tendon). While tension is applied to both holding sutures, each is secured with a Kocher clamp at its tibial insertion in such a way that the semitendinosus loop is approximately 1 cm longer than the smaller gracilis loop. Alternatively, if long enough, the semitendinosus tendon graft may be tripled for the replacement of the stronger anterolateral bundle. Using a baseball stitch, the 4 tendon strands are sutured together over a length of 3 cm at the end that is still attached to the tibia. Both loops of the tendon strands are sutured individually over a length of 2 to 2.5 cm using a baseball stitch (Fig 2). The graft is cut off and the length (approximately 9 cm) and the exact diameter of the graft ends are measured using the sizing holes of a graft preparation block. Finally, 4 No. 5 Ethibond sutures (Ethicon, Somerville, NJ) are attached to the distal graft end using a modified Bunnel stitch.

Tunnel Creation

After a thorough and careful arthroscopic examination of the knee, the knee joint is flexed to 80°. The ruptured PCL is removed from the medial wall of the intercondylar notch. A small remnant is left attached to the medial wall to mark the footprint of the original PCL. The entrance of the more superior of the 2 femoral sockets is marked approximately 13 mm below the top of the roof and 13 mm posterior to the border of the articular cartilage using an angled awl (Fig 3).[33] The more inferior socket entrance is marked

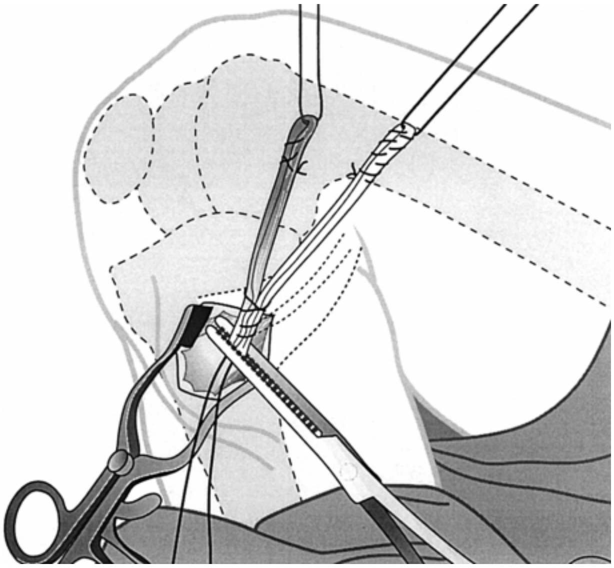


Figure 2. Both loops of the tendon strands are sutured individually over a length of 2 cm using a baseball stitch.

approximately 20 mm down from the top and just 8 mm away from the border of the articular cartilage (Fig 3).[33] A 7-mm blade dilator is inserted through the additional low anterolateral arthroscopic portal into the knee joint. It is driven into the bone at the previously marked entry points for the femoral sockets. Once the 40-mm long dilator is inserted about half way, an oscillating motion of the dilator will create a cylindrical hole (Fig 4). In very dense bone, we recommend widening the first few millimeters of the socket entrance to 9 mm.

At this point, one might want to establish an additional posteromedial portal. This portal lies approximately 2 to 3 cm above the joint line. Under direct arthroscopic vision, a long spinal needle is inserted to find the optimal location. Through this portal, under direct vision of the anteriorly introduced arthroscope, the exit of the tibial tunnel can be cleaned of any remnants of the PCL. Thus, the arthroscope may be switched to this posteromedial portal to visualize the future tunnel exit point (Fig 5). The hook of the PCL tibial drill guide is introduced into the knee joint through the anteromedial portal and pushed far back over the top of the tibial plateau (Fig 6). Its correct position is verified under direct arthroscopic vision through the posteromedial portal and, if desired, by fluoroscopy. The entrance to the tunnel has to be located just medial to the tibial tubercle. Under arthroscopic control, a 2.4-mm K-wire is drilled so that its exit point corresponds to the center of the spoon of the tibial drill guide. The length of the tibial tunnel is then measured. The tibial drill guide is removed, leaving

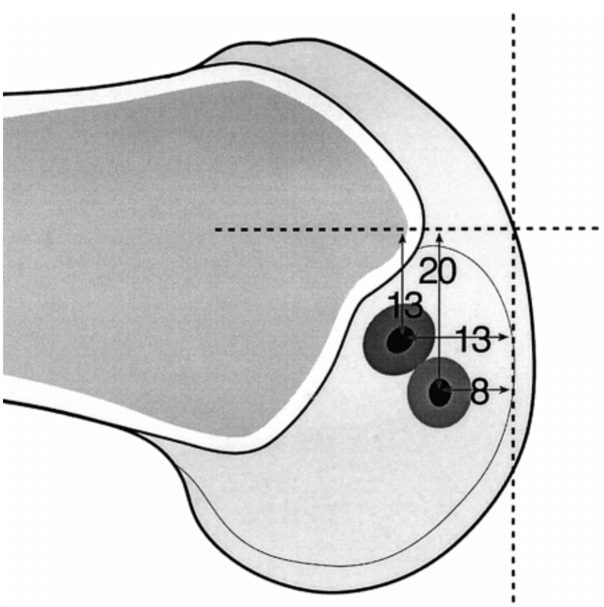


Figure 3. The entrance of the more superior of the 2 femoral sockets is marked approximately 13 mm below the top of the roof and 13 mm posterior to the border of the articular cartilage. The more inferior 20 mm down and 8 mm posterior.[33]

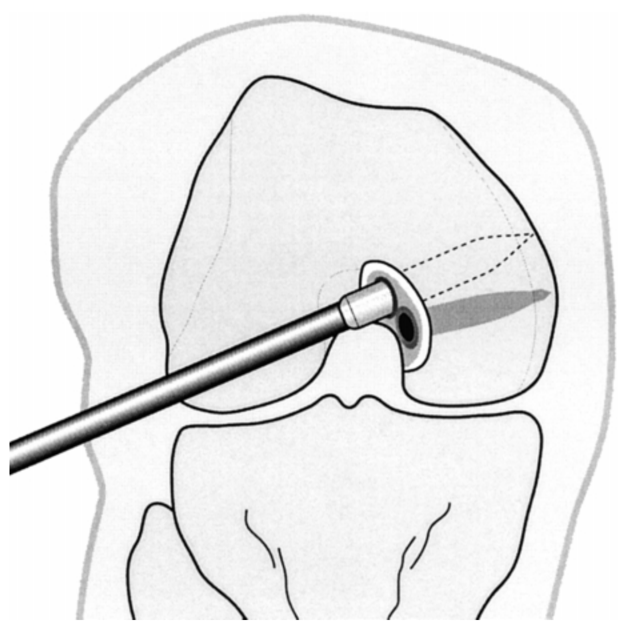


Figure 4. Once the 40-mm long 7-mm wide femoral dilator is fully inserted, an oscillating motion of the dilator will create a cylindrical hole.

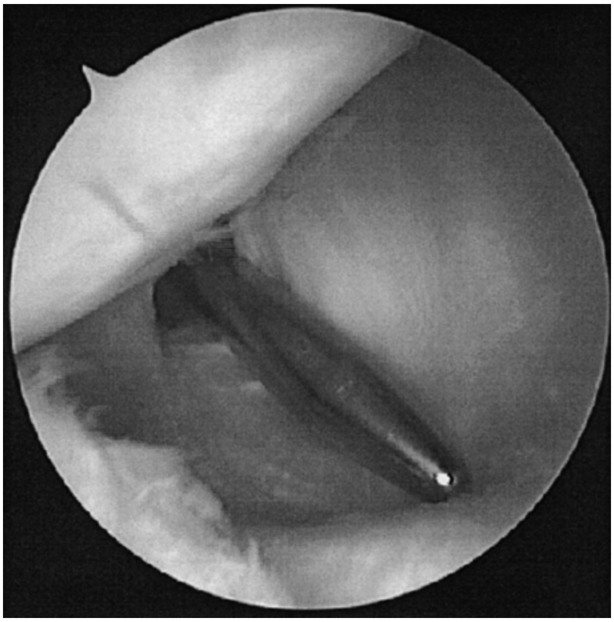


Figure 5. A Wissinger rod is placed through the posteromedial portal for the insertion of the arthroscope.

the guidewire. The anterior cortex of the tibial tunnel is opened by using a cannulated drill bit, preferably of the same size as the final tibial tunnel diameter over the guidewire. Then the tunnel is dilated using cannulated tibia dilators sizing up to the desired diameter of the tunnel in 1-mm steps up to about 1 cm below the joint. A transtibial tube saw is then used to penetrate the dense subchondral bone and to remove the remnants of the old PCL (Fig 7). Using the hand-driven transtibial tube saw, the tunnel exit point can be slightly corrected in any direction. Once the tube saw enters the joint, it is advanced further with an oscillating motion to resect all soft-tissue fibers remaining at the tunnel exit.

Graft Passage and Fixation

Using a beath pin with suture, a loop of a white nonresorbable suture (for the semitendinosus tendon) is pulled via the anterolateral arthroscopy portal into the superior femoral socket and out of the lateral femoral condyle (Fig 8A). The suture is pulled until a just small loop protrudes out of the femoral socket. Using a pigtail suture passer, a white pull-through suture is inserted into the tibial tunnel and brought over the top of the posterior border of the tibial plateau. An arthroscopic grasper is now inserted through the loop of the previously placed white suture lying inside the superior femoral socket and the suture is pulled out the anteromedial portal (Fig 8B). The suture loop and, with it, the suture coming from the tibial tunnel, is now pulled out of the medial femoral condyle and the skin. The same procedure is performed using a colored pull-through suture for the inferior socket. This way, both pull-through sutures are placed through the tibial tunnel, each into 1 of the femoral sockets. The 2 sutures of the femoral ends of the graft are now tied to the pull-through sutures. The white pull-through suture is attached to the semitendinosus tendon and the colored pull-through suture to the gracilis tendon. The graft is now pulled through the tibial tunnel into the femoral sockets. The graft pas-

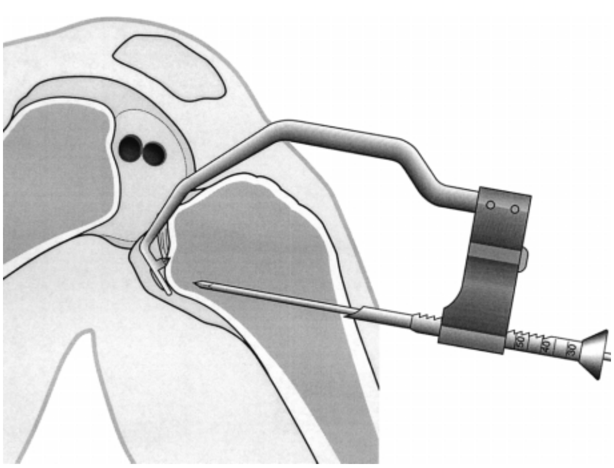


Figure 6. The hook of the PCL tibial drill guide is introduced into the knee joint and pushed far back over the top of the tibial plateau.

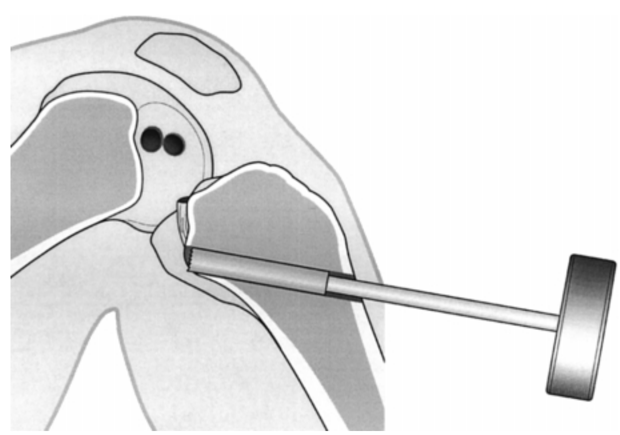


Figure 7. The tibial tunnel is created by using cannulated dilators in increments of 1 mm. The dorsal tibial cortex is penetrated with a hand held helical tube saw and the remaining soft tissue is removed.

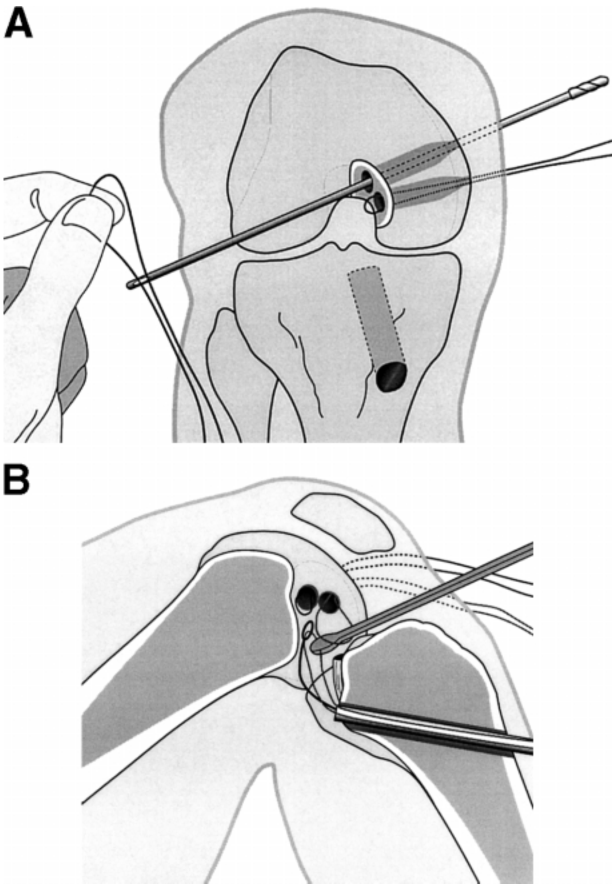


FIGURE 8. (A) A beath pin with suture is pulled via the anterolateral arthroscopy portal into the superior femoral socket and out of the lateral femoral condyle. (B) An arthroscopic grasper is inserted through the suture loop and the suture from the tibial tunnel is pulled out the anteromedial arthroscopy portal.

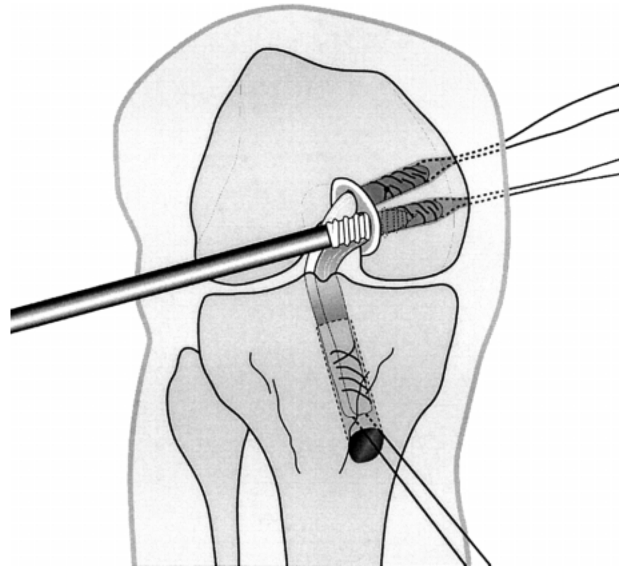


FIGURE 9. With the knee flexed to 80°, the first biodegradable interference screw is inserted from the low anterolateral arthroscopic portal into the inferior femoral socket.

sage can be easily facilitated by inserting a blunt trocar into the posteromedial portal and using it as a fulcrum. Both femoral ends are pulled for at least 25 mm inside the femoral sockets so that the sutures in the tendons are no longer visible.

With the knee flexed to 80°, the gracilis bundle is fixed using the first biodegradable interference screw (Sysorb; Sulzer Orthopedics Ltd, Baar, Switzerland). The screw is inserted from the low anterolateral portal into the inferior femoral tunnel (Fig 9). The graft is held tightly with the holding sutures to prevent the screw from catching some of the superficial graft fibers. The screw is inserted just underneath the joint surface. Then a pretensioning force of 80 N is applied to the tibial end of the graft using the tension isometer. The joint is moved through its full range of motion several times and the knee is brought to the near extension position. Maintaining the pretension to 80 N, the tibial biodegradable interference screw is inserted parallel to the graft using a cannulated screwdriver over a small nitinol guidewire (Fig 10). The screw is advanced until the marking on the screwdriver corresponding to the previously measured tunnel length reaches the tibia cortex at the tibial tunnel

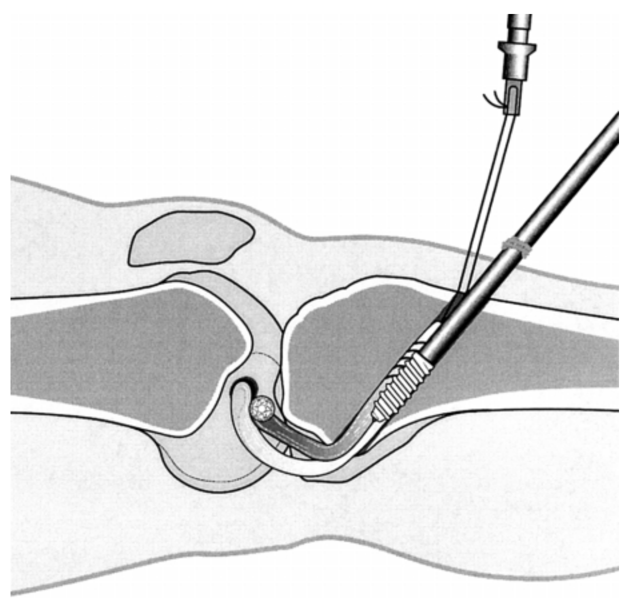


FIGURE 10. The tibial biodegradable interference screw is inserted parallel to the graft in full extension using a cannulated screwdriver over a small nitinol guidewire.

entry. The knee is now flexed to 80° and 80-N pretension is applied to the anterolateral semitendinosus loop. Then, the third interference screw is inserted in the same manner (Fig 11). To augment the tibial fixation, we recommend tying the distal holding sutures around a bony bridge at the outer edge of the tibial tunnel. In the final reconstruction, the anterolateral bundle is tight in flexion and the posteromedial is tight in extension (Fig 12).

Posterolateral Stabilization

In cases of more than 12 mm posterior drawer in 90° flexion on stress radiographs, with an increased external rotation or an increased lateral joint opening during arthroscopy, we perform an additional posterolateral stabilization.[34-36] The posterolateral stabilization is modified according to the technique described by Strobel[37] using a semitendinosus tendon harvested from the opposite knee or allograft material.

A 4.5-mm oblique hole is made in the fibular head. The optimal isometric location of the femoral hole should be verified using a suture passed through the tunnel of the fibular head and fixed to the femur using a K-wire (Fig 13). This point lies near the lateral femoral epicondyle at the proximal attachment site of the lateral collateral ligament. Once there is little change in the suture length during a full range of

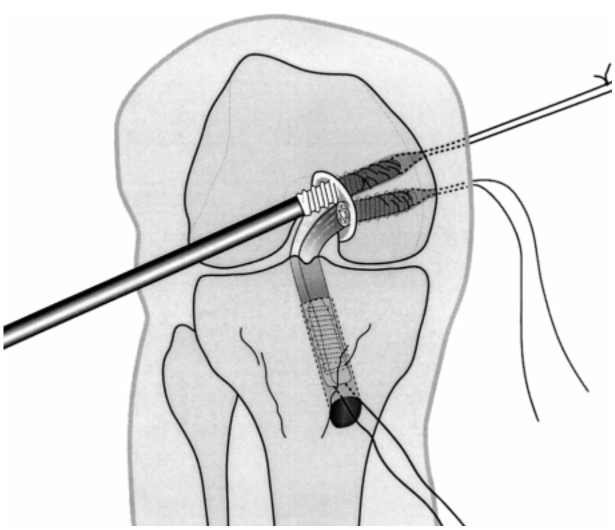


FIGURE 11. The third interference screw is inserted in the same way as the first (with the knee flexed to 80°) in the superior femoral socket.

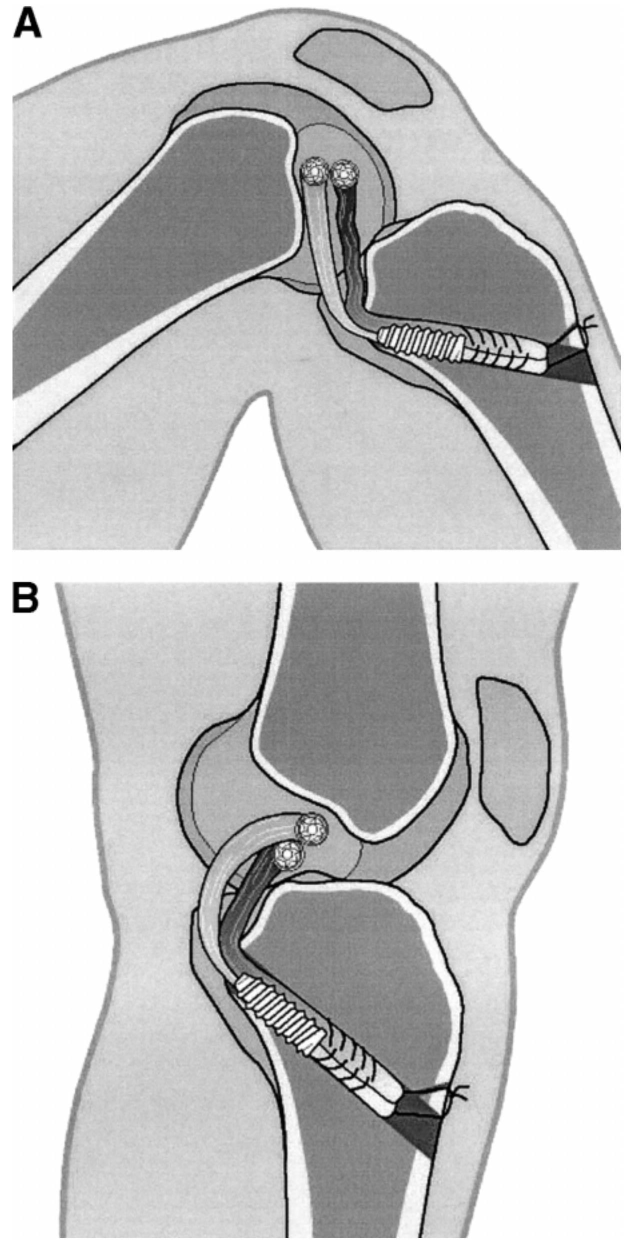
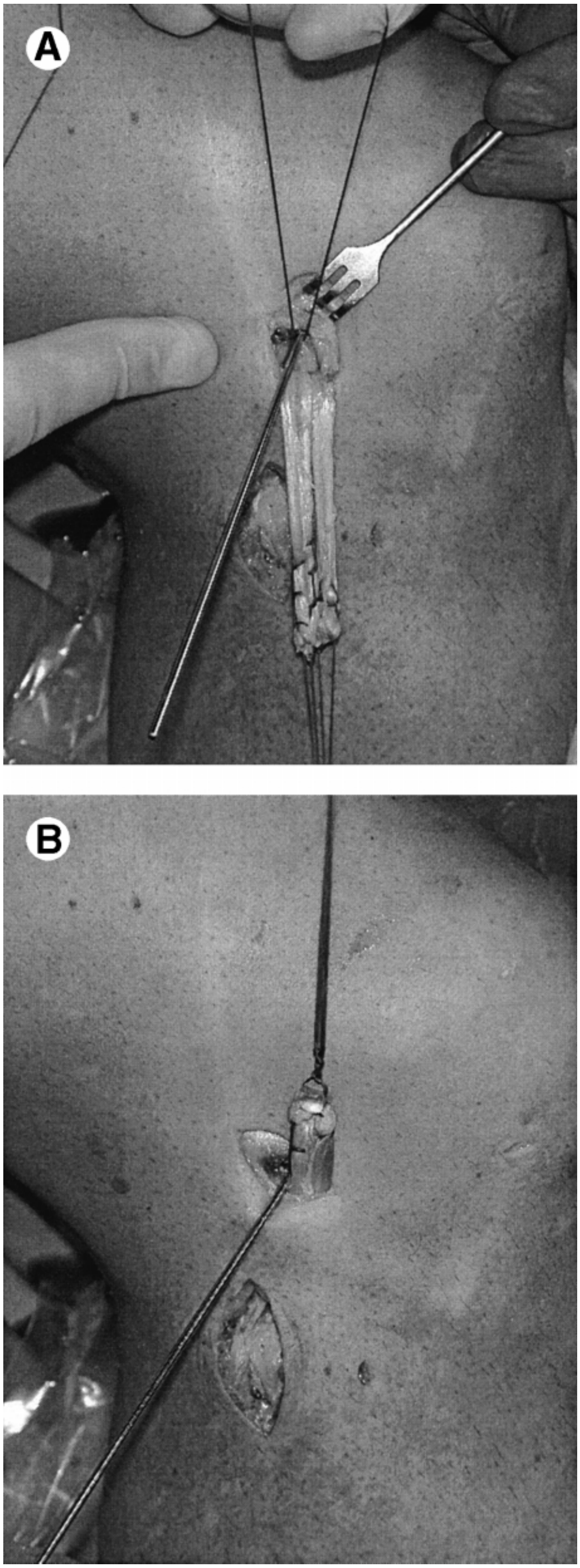


FIGURE 12. In the final reconstruction, (A) the anterolateral bundle is tight in flexion and (B) the posteromedial bundle is tight in extension (b).

motion (approximately less than 2 mm) a 7-mm wide 40-mm long hole is created using the Sysorb screwdriver (Sulzer) first and then the 7-mm dilator. The semitendinosus graft is pulled into the socket using a beath pin. The graft is pretensioned and fixed directly to bone in 60° of flexion and slight internal rotation using a single biodegradable screw (Fig 14).



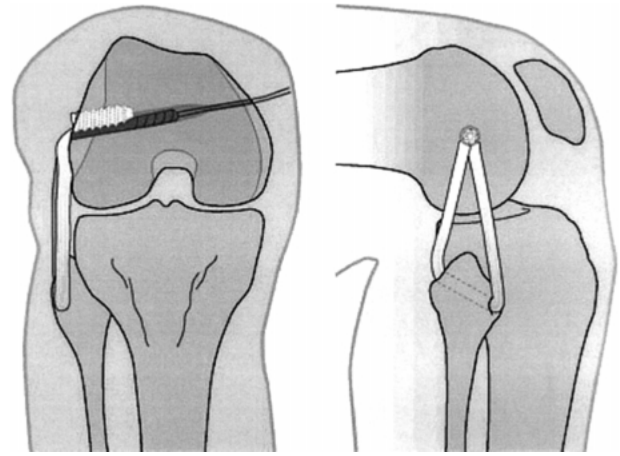


FIGURE 14. Final appearance of the posterolateral reconstruction. The semitendinosus graft is pulled into the socket using a beath pin. The graft is pretensioned and directly fixed to bone using a single biodegradable screw.

Postoperative Rehabilitation

The knee joint is immobilized in full extension using a posterior tibial support brace (PTS Brace; Medi Bayreuth GmbH, Bayreuth, Germany) (Fig 15). This reduces posterior subluxation and is worn for 6 weeks during the day and at night. Quadriceps strengthening exercises are started after the first week and full weight bearing is permitted as tolerated. Passive flexion exercises limited to 90° are performed in the prone position. After 6 weeks, the PTS Brace is worn only at night for another 6 weeks in order to eliminate posterior sagging during the night. During that time, a functional PCL Brace is worn during the day.[2]

DISCUSSION

The technique of double-bundle PCL reconstruction using hamstring tendons and soft threaded biodegradable interference screws for fixation described in this report offers distinct advantages. The use of autologous hamstring tendons as compared with patellar

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FIGURE 13. To detect the most isometric point, a K-wire is inserted slightly proximal and anterior to the femoral insertion of the lateral collateral ligament. Isometry is checked by an additionally inserted suture during a full range of motion. (A) If suture excursion exceeds approximately 2 mm, the K-wire position has to be changed. (B) The graft is then shortened to the desired length. In this case, an additional EndoPearl device (Linvatec, Largo, FL) is attached to the graft to augment the fixation.

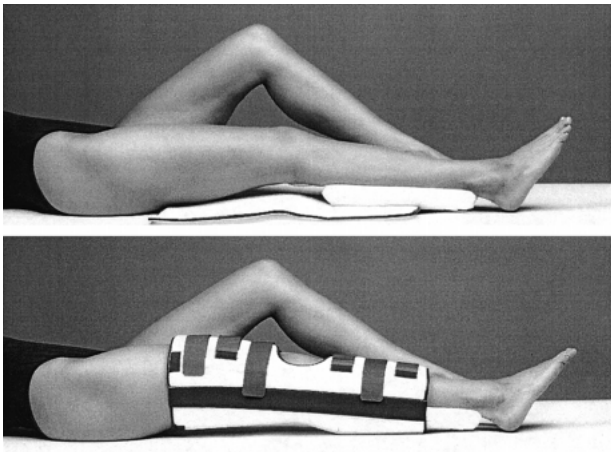

FIGURE 15. The PTS Brace locks the knee in full extension. The additional inlay at the calf reduces the posterior subluxation.

tendon autograft is associated with a reduced harvest site morbidity, and without attached bone plugs, graft-passage is easily facilitated. A single tibial tunnel and 2 femoral sockets allow good restoration of the anatomy of the natural PCL whose fibers diverge widely as they approach the extensive femoral attachment.[38-41] The femoral sockets are created from inside out through an additional low anterolateral working portal as first described by Kim and Min.[32] This makes an incision at the medial femoral condyle unnecessary, thus reducing the overall morbidity.[42] For graft fixation, the interference screws are inserted through the same portal and in the same direction as for the creation of the tunnel. This reduces screw divergence and increases screw fixation strength.[43,44] The use of biodegradable interference screws offers several advantages over their metal analogues, such as undistorted magnetic resonance imaging, uncompromised revision surgery, and a reduced risk of graft laceration during screw insertion.[45-49]

Soft threaded biodegradable interference screws (Sysorb) allow hamstring graft fixation close to the original PCL attachment site, which might increase the immediate postoperative posterior knee stability as was shown for ACL reconstruction[20,50,51] because the free graft length is reduced to its intra-articular portion. Thus, the free part of the graft is no longer than the intra-articular distance, which reduces elastic elongation of the graft construct. Furthermore, anatomic joint line fixation promotes soft-tissue graft incorporation into the bony tunnels.[23,52,53]

In the native PCL, the thinner posteromedial bundle is tight in extension and the stronger anterolateral bundle is taught in flexion.[28,29] The fixation of the 2 bundles in our method takes this fact into account and the anteromedial bundle is tensioned and fixed in near extension, whereas the anterolateral bundle is anchored in flexion. Race and Amis[31] were able to prove that an anatomic double-bundle PCL reconstruction is superior in restoring normal knee laxity compared with a single-strand, so-called isometric reconstruction.[31]

Fixing the knee joint in full extension first is especially advantageous in cases where both the ACL and PCL are disrupted (Fig 16) and the neutral position of the knee joint cannot be easily detected. Because the medial tibiofemoral joint is congruent, the knee joint can be reduced to neutral with full extension and axial loading, at which time the posteromedial bundle is fixed. If necessary, the additional posterolateral stabilization using the contralateral semitendinosus tendon or allograft material and direct tendon-to-bone interference screw fixation is minimally invasive and effectively reduces increased posterolateral rotatory instability.[37] Our preliminary clinical experiences are encouraging as are those recently reported by Caborn et al.[54] However, long-term data are necessary to finally judge on this new operative procedure.

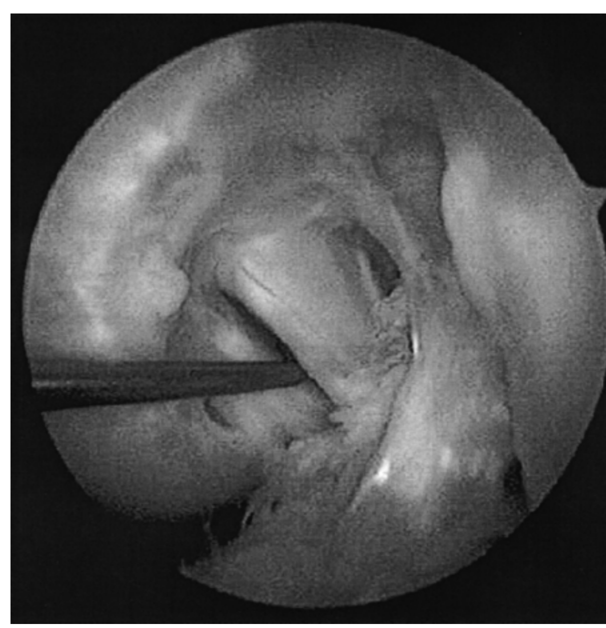

FIGURE 16. Second-look arthroscopy 1 year after combined ACL, PCL, and posterolateral reconstruction. The probe indicates the separation of the anterolateral and posteromedial bundle.

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