Imaging of posterior cruciate ligament (PCL) reconstruction: normal postsurgical appearance and complications

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Learning objectives

1. To describe the normal postsurgical appearance of a posterior cruciate ligament (PCL) reconstruction and the donor sites on multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI), considering the different surgical techniques.
2. To evaluate imaging signs of PCL graft failure and its possible causes on MDCT and MRI, including tunnel placement and other relevant parameters.
3. To review the potential complications associated with PCL reconstruction and their imaging appearance.

Background

The management of ligamentous lesions of the knee has evolved greatly in the past decades. PCL lesions are much less frequent than anterior cruciate ligament (ACL) injuries, and many are partial-thickness tears that may be managed conservatively (1-4). However, it is currently recognized that PCL lesions have a significant impact on the biomechanics and stability of the knee (1-4). Advances in the surgical techniques and knowledge of the risk of osteoarthritis derived from a chronic instability due to PCL deficiency have motivated an extension of the indications for PCL repair and a relative increase in the number of surgeries (1, 2).

Imaging has also undergone significant progress and there is greater experience in the evaluation of postsurgical knees. Yet PCL reconstruction possibly because it is less performed and to the lack of standardization in the surgical techniques, remains an almost unexplored territory for radiologists with scarce publications on the imaging findings (1, 4).

The success of the repair technique depends greatly on tunnel positioning, but there are multiple factors that may contribute to the failure of the PCL reconstruction.

We will present a brief description of the most widespread surgical techniques for PCL reconstruction and review their normal postsurgical appearance on MDCT and MRI, including the findings at the donor sites. We will assess the imaging findings of graft failure and other potential complications, of the graft and at the donor sites.

Imaging findings OR Procedure details
The **indications** for PCL reconstruction are: acute PCL lesions with significant instability (grade 3+), bone avulsion fractures, combined multiple ligament injuries or chronic symptomatic PCL laxity (1, 2, 4).

**SURGICAL TECHNIQUES**

PCL reconstruction techniques have gained interest and have developed considerably in the last decades, although there is no accepted standard technique and the choice of the surgical technique remains a controversial topic (3, 5).

The objective of the surgery is to restore ligament function with a graft which resembles the native ligament, obtaining isometry of the total ligament mass (not of the independent bundles) without producing impingement, laxity or overtensioning of the graft (1, 6). The PCL can be repaired in isolation or together with other ligaments (ACL, posterolateral corner...) in combined ligament injury (3, 7).

The native PCL is formed by 2 bundles: anterolateral (AL) and posteromedial (PM), although it could be described as a continuity of fibers which rotate during the flexion-extension cycle of the knee (3). Knowledge of the insertion sites of the native PCL in the femur and tibia helps in the positioning of the tunnels for PCL reconstruction (Fig. 1 on page 12). It is generally accepted that optimal positioning of the graft is that which most closely resembles the native PCL (6-8). Several authors have demonstrated that femoral tunnel placement is more important than the tibial tunnel position, since its influence on the laxity of the graft and its clinical effect is less clear (2, 5, 7, 8).

Surgical techniques vary according to (3, 9, 10):

- Tibial fixation technique
- Single or double bundle
- The type of tendinous graft
- The fixation material

Currently, 2 differentiated techniques for **tibial fixation** are used (Fig. 2 on page 13) tibial inlay and transtibial techniques. In the **inlay technique**, the end of the graft is directly fixated to the tibia (2, 6, 10). This technique supposedly should avoid the so-called **killer turn** (See Fig. 17 on page 26) which occurs in the transtibial technique at the opening of the tunnel, although its superiority has not been demonstrated (3, 9). In the **transtibial technique**, a tibial tunnel is drilled from anterior to posterior with arthroscopic...
visualization of the native PCL tibial insertion site. After adequate tensioning of the graft and reduction of the posterior drawer, both ends are fixated (2).

The choice of the number of **single or double bundle** (and accordingly single or double femoral tunnel) (Fig. 3 on page 13) is controversial. The single-bundle technique is limited to reconstructing the more potent anterior bundle, but it has been described that it does not limit the posterior displacement of the tibia (in 90° flexion). Hypothetically, the double bundle technique, which more closely resembles the native PCL, would be more effective in controlling posterior stability in every degree of flexion, but there is no consensus in the literature, and it adds technical difficulties (3, 5, 11).

When considering the selection of the **type of graft**, the tibial inlay technique is usually performed with autologous bone-patellar tendon-bone (BTB) grafts or allograft of diverse origin, most commonly Achilles tendon (1). Transtibial technique usually implies the use of hamstring tendon grafts (most frequently), BTB or allografts (1, 2, 10).

**BTB grafts** are generally chosen in young athletes, since they allow a quick re-establishment of physical activity (1, 6). The major disadvantage of this technique is the appearance of complications at the donor site (1) and many times a graft which is too short for adequate PCL reconstruction. The tendon graft is harvested from the central third of the patellar tendon along with two bone plugs from the inferior pole of the patella and the tibial tuberosity (1, 2, 6).

The use of **hamstring tendon grafts** has spread in recent years mainly because of the development of the fixation devices (1). The advantages of this technique include the absence of complications in the anterior region of the knee, the small incision required in the extraction site and the regeneration of these tendons, recovering up to 95% of their preoperative strength within 3 years (1). The disadvantage is the possibility of tunnel expansion in the long term. Tendon grafts are obtained from 2 tendons, usually gracilis and semitendinous tendons, harvesting fibers from the tibial insertion up to the myotendinous junction, acquiring long fibers which are then folded over and sutured together, resulting in a graft composed of several bundles (1, 2). The donor tendons lose their distal insertion (1).

There is an ample range of options in the **fixation material** (Fig. 4 on page 14). 2 main basic categories of fixation techniques may be distinguished: bone plug graft fixation and soft-tissue fixation. Bone plugs in BTB grafts proceed from the donor site or are obtained from the drilling of the tibia in the transtibial technique. There is a great variety of soft-tissue fixation devices, including metallic staples and screws, cross-pins, endobuttons and resorbable screws (1).
NORMAL POSTSURGICAL FINDINGS

NORMAL POSTSURGICAL APPEARANCE OF THE PCL GRAFT

MRI is the imaging technique that offers the most widespread assessment of the ligament reconstruction since it allows evaluation of the ligament graft, the tunnels and the potential complications (8, 10, 12). The tunnels and the fixation material may also be assessed with MDCT or even radiographs.

MRI protocols may vary between different centres but, as a general rule, for evaluation of a ligament reconstruction it is convenient to include an acquisition in an oblique sagittal plane following the course of the graft. The amount of magnetic susceptibility artifacts depends on the type and quantity of fixation material (1) (Fig. 5 on page 15). In PCL reconstructions, contrasting with ACL reconstructions, these artifacts may truly hinder the evaluation of the graft due to a more proximal location of the tibial fixation, especially in tibial inlay reconstructions (1, 2). In spite of the artifacts, an acceptable evaluation of the intraarticular course of the graft is usually possible in isolated PCL reconstructions (1, 2, 12), not so when there is combined multiple ligament reconstruction. Depending on the amount of artifacts, the use of fat saturation sequences will be more or less limited. In general, gradient echo sequences are discouraged due to this reason.

We need to assess the appearance of the ligament graft, the morphology and position of the tunnels and the condition of the fixation material.

LIGAMENT GRAFT

The ligament plasty itself can only be evaluated by MRI, although indirect signs of its status are reckonable with other techniques. The MR appearance of the PCL plasty varies significantly depending on the type of graft, the fixation technique and the time elapsed since the surgery (1, 10). The plasty is better evaluated on T2-weighted sequences (T2WI) and tunnel positioning on sagittal images (1, 5).

The MR signal intensity varies with the age of the graft, i.e. the time elapsed since the surgery (1, 5, 10). In the first 3-4 months, the graft is avascular and will show signal intensity similar to that of the donor tendon: hypointense on all sequences (1). Most authors concur that 4-8 months after the surgery, the tendinous graft undergoes a remodelling and resynovialization process called "ligamentization", since it morphologically and histologically transforms into a tissue similar to the native PCL (1, 2, 4, 10). During this remodelling phase, a high signal intensity on T2WI may appear which should not be mistaken for a tear. The signal intensity should always be lower than fluid signal (1), and fibre continuity must be observed. After 1-2 years after surgery the
appearance of the graft should be similar to the native PCL, hypointense on all sequences (1, 2, 4, 10) (Fig. 6 on page 16).

However, hamstring tendon grafts present a notable difference with BTB grafts due to their internal configuration with several bundles described previously: longitudinal linear images of intermediate signal intensity may be observed between the bundles, or even of high signal intensity of fluid enters the space between the bundles, representing a normal finding that would be clearly abnormal in a BTB graft formed by a single bundle (Fig. 7 on page 18)(1, 2, 4). These small laminar collections are usually reabsorbed during the first or second year after the surgery and should be distinguished from a ganglion cyst (1).

Arthrofibrosis is a very frequent finding in PCL reconstructions, much more than in ACL plasties, owing mainly to movement restriction on the immediate postoperative period. It is hypothesized that it may actually contribute to stabilization of the knee after ligament reconstruction and therefore a certain degree of arthrofibrosis may be considered a normal finding, considering it does not limit range of motion (1, 2, 13) (see Fig. 18 on page 27).

TUNNELS

Contrasting ACL plasties, there are scarce publications on tunnel positioning in PCL reconstructions (1, 2, 8). The position of the tunnels may be assessed with different imaging modalities. Plain radiographs are probably the most accessible, but interpretation is variable (6-8). MDCT and MRI allow a more precise evaluation of the tunnels, although MDCT offers a more precise vision of the bony tunnels (5, 7, 8).

Mariani et al. (8) published a method for evaluation of tunnels with MRI (Fig. 8 on page 18 and Fig. 9 on page 19) for techniques with a single femoral tunnel. Axial, sagittal and oblique coronal images are used.

The axial image, obtained at the level of the tibial plateau, determines the T1 point or site of tibia insertion of the PCL. Lines are drawn through the maximum AP diameters of the tibial plateaus (medial and lateral). The centre points of each line are then joined creating a new line. A perpendicular line to the centre of this line indicated the joint midline. The ideal site of insertion is located on that point or minimally medial to it.

The sagittal image at the site of femoral insertion of the PCL determines the F1 point, which indicates the deep or superficial position of the femoral insertion of the PCL. Blumensaat's line is divided into 4 quadrants, I-HV. Zone I is the optimal position for fixation and is less associated with posterior laxity of the knee.
The oblique coronal image, perpendicular to Blumensaat’s line, determines the F2 point, the coronal location of the femoral insertion site of the PCL. It indicates the high or low insertion in the medial wall of the intercondylar notch. A ratio is calculated between 2 distances to a line connecting the articular surfaces of both condyles, from the roof of the intercondylar notch and from the centre of the PCL insertion in the medial femoral condyle. It should be placed approximately at 8.5 mm.

Gancel et al. (7) described a method for assessment of the tunnels with CT (Fig. 10 on page 19 and Fig. 11 on page 20), also for single tunnel technique.

The tibial insertion site is measured in the coronal and sagittal planes. On the coronal plane a line is traced through the mediolateral diameter of the tibial plateau, marking a 5 mm interval centred on a point 48% from the medial border. A line traced from the medial border of the tibial plateau to the centre point of the articular opening of the tibial tunnel should fall into the marked interval. On the sagittal plane, a line is traced following the retrospinal surface, marking a 5 mm interval in the posterior half. A line traced from the posterior end of the tibial spine to the articular opening of the tunnel should fall into the marked interval.

The femoral insertion site is evaluated in the sagittal and axial planes. On a sagittal image at the level of the medial femoral condyle, the distance between the centre of the tunnel and the articular surface is measured, which should be around 10 ±2.5 mm. On the axial plane, a clock face is drawn on the intercondylar notch, with 3 o'clock and 9 o'clock placed at the base of the intercondylar notch and the connecting line between these hours is parallel to the posterior border of the condyles. The position is considered adequate between 10:30 - 11.30 for the left knee and 12:30-1:30 for the right knee.

Unifying both criteria, and in accord with other publications in the literature, we may simplify the location of the tunnels as follows: the optimal location of the articular opening of the femoral tunnel depends on the election of single or double bundle. In the single tunnel technique, the opening will be located near the femoral insertion of the AL bundle, in the anterior half of the insertion site of the native PCL, at 1 o'clock or 11 o'clock, in the right and left knee respectively, and 8-10 mm from the articular margin (2, 5-7). In double femoral tunnel reconstructions, the articular opening sites should be located one in the anterior third of the native PCL insertion site and the other in the middle to distal third, at 1 o'clock and 3 o'clock (right knee) and at 11 o'clock and 9 o'clock (left knee) (5, 11). The tibial fixation site in both techniques (inlay and transtibial) will be located in the middle of the posterior half of the retrospinal surface, immediately medial to the articular midline, 8-15 mm distal to the articular surface (2, 3, 6-8).

In general, a small variability in tunnel positioning is allowed, and it is not clear what degree of precision is required to avoid graft disruption, laxity or impingement (2, 3, 7, 8). It is considered that a tunnel is abnormally placed when 75% or more of the
articular opening lies outside the anatomic insertion site (5). The most frequent mistakes in tunnel positioning are an excessively posterior situation of the femoral tunnel or an excessively proximal position of the tibial tunnel, determining a very vertical graft with limited competence to resist posterior tibial translation (5).

Preservation of the femorotibial alignment should be assessed on sagittal images (See Fig. 15 on page 24 and Fig. 16 on page 25).

In the early postoperative period and up to 12 months following surgery, a variable degree of persistent bone marrow edema may be seen around the tunnels (1). A slight radiolucency surrounding the graft may also appear before bone plug incorporation (6). With time, it is not infrequent to see sclerosis of the tunnels (6) (Fig. 12 on page 22).

**FIXATION:**

Metallic fixation devices generate significant artifacts that persist indefinitely, whereas resorbable materials produce less artifacts that tend to diminish overtime, allowing better evaluation of the graft and bone tunnels (1, 12) (See Fig. 4 on page 14 and Fig. 7 on page 18). In the fixation sites a variable degree of bone marrow edema may be seen in the early postoperative period (1).

**NORMAL POSTSURGICAL APPEARANCE OF THE DONOR SITES**

In **BTB** technique (Fig. 13 on page 22) a central defect of about 5 mm will be appreciated in the patellar tendon and small bone defects in the inferior pole of the patella and tibial tuberosity. Usually in the first 2 years following surgery this defect is occupied by a tissue indistinguishable by MRI from the native tendon, showing hypointense signal intensity on all sequences. Initially the patellar tendon will appear thickened and with increased signal intensity on T1 and T2WI. If thickening >10 mm or hyperintensity persist overtime, patellar tendinopathy should be considered (1).

In **hamstring grafts** (Fig. 14 on page 23) during the first month after surgery it is usual to see small laminar fluid collections in the donor site following the course of the grafted tendons. In the following 6-12 months, signs of tendinous regeneration will be progressively appreciated in these areas, with persistent tendon thickening extending 1-2 cm proximal of the tibial insertion. This distal portion usually does not recover and will maintain an ill-defined appearance with increased signal intensity. After the first year after surgery, it is difficult to detect the postsurgical changes at the donor site, except at
the tibial insertion site of the grafted tendons, and there is usually no significant atrophy of the corresponding muscles (1).

COMPLICATIONS

COMPLICATIONS OF THE PCL LIGAMENT GRAFT:

Several complications may occur following PCL reconstruction, and imaging plays a key role in the evaluation of symptomatic patients after surgery. According to the clinical symptoms, different complications may be distinguished:

1. Unstable knee: we will suspect graft failure either due to disruption or laxity.
2. Limitation of flexion-extension of the knee: it may be secondary to graft impingement, arthrofibrosis or presence of intraarticular loose bodies (1, 12).
3. Persistent knee pain, which may be due to multiple causes.

PCL GRAFT DISRUPTION

Disruption of the PCL graft (Fig. 15 on page 24) may occur at any moment following reconstruction; however the graft is most vulnerable during the remodelling phase (1, 10). Theoretically, the graft is equivalent to the native PCL since the first year after surgery (1). Disruption of the graft may be secondary to a new traumatic mechanism or to chronic impingement.

Absence of visualization of the graft or presence of a full-thickness defect of fluid signal intensity are the most specific signs of graft disruption (1, 2, 10). We have to consider the time elapsed since the surgery, since hyperintensity on T2WI is a normal finding in the remodeling phase. An indirect sign of disruption is the posterior displacement of the tibia with respect to the femur, which is the imaging equivalent to the posterior drawer test (1, 7, 10).

GRAFT LAXITY

Laxity or stretching of the PCL graft (Fig. 16 on page 25) should be considered if there is knee instability with integrity of the graft fibers on MRI. Bowing or buckling of the plasty may be observed.
Graft laxity is believed to be more likely with hamstring grafts. In the majority of cases, surgical intervention is required to recover stability, either by means of graft tightening (radiofrequency heat shrinkage) or by new ligament reconstruction (1). It is important to distinguish laxity from graft tear if the option of tightening is considered.

GRAFT IMPINGEMENT

Graft impingement (Fig. 17 on page 26) is a noteworthy complication, since it usually presents with flexion-extension limitation but may derive in graft tear.

Erroneous location of the tunnels or the killer turn in the transtibial technique may cause a forced position of the ligament graft, causing friction with the bony structures which will eventually cause fraying, fibrosis, tears in the graft bundles and subsequent complete disruption (1).

On MRI, thickening and high signal intensity on T1 and T2WI may be noticed in the intraarticular course of the graft (1, 10). This finding should not be confused with the normal hyperintensity observed during the remodelling phase, which should resolve. In case of impingement, the high signal intensity does not diminish, but persists or worsens overtime (1, 10). Another sign of impingement is buckling of the graft at the articular opening of the tunnels (1).

ARTHROFIBROSIS

Arthrofibrosis may cause pain and flexion-extension limitation of the knee. However, as mentioned previously, in PCL reconstruction a slight arthrofibrosis may be considered a normal finding (1, 2, 13).

There are 2 types of arthrofibrosis (Fig. 18 on page 27) focal and diffuse (1). Focal arthrofibrosis is also known as "cyclops lesion" due to its arthroscopic appearance. It consists of nodule of fibrous tissue, typically located around the PCL graft or in Hoffa's fat pad (1, 2), and it is better defined on sagittal images. Due to its fibrous nature, it appears hypointense on all sequences, although it may present a variable signal intensity on T2WI (1, 2, 10). The diffuse form generally presents as a spiculated ill-defined mass of low signal intensity (1).
Cyclops lesions do not generally produce significant movement restriction, but may generate recurrent joint effusions related with activity. Symptomatic arthrofibrosis requires arthroscopic resection (1, 10).

GANGLION CYST FORMATION

Ganglion cyst formation (Fig. 19 on page 28) may cause degeneration or partial tear of the PCL graft (1, 10). It appears to be more common with hamstring tendon grafts and allografts (1, 5). There is controversy as to its relation with graft failure (1, 10).

In general, ganglion cysts are formed in the interior of the tibial tunnel and as they grow, they may protrude proximally into the joint or distally into the soft tissues adjacent to the extraarticular opening of the tunnel (1). They are associated to widening of the tunnels (10). Ganglion cysts may be asymptomatic or cause pain, flexion-extension limitation or palpable mass (1).

On MDCT these lesions appear as a fluid density mass, or as widening of the tunnels with wall remodeling or loss of definition of the cortical borders. On MRI we can observe a lobulated cystic structure with fluid signal intensity (1). They must be discriminated from the normal laminar fluid collections that may appear in hamstring tendon grafts previously described.

TUNNEL WIDENING

Widening of the tunnels (Fig. 20 on page 29) may be caused by incomplete incorporation of the graft in the tunnel or as the effect of a ganglion cyst, although in the majority of cases the cause remains unknown (10). It is considered significant if there is an increase of 50% or more of the area of the tunnel (5). If there is significant widening, movement of the graft inside the tunnel may occur, termed "windshield wiper effect" (10), that does not usually have relevant consequences.

COMPLICATIONS RELATED WITH THE FIXATION MATERIAL

The fixation material may shift or rupture (Fig. 21 on page 29) (6). Both complications are better evaluated on radiographs or MDCT. If the fixation material protrudes into the periarticular soft tissues, it may cause pain, inflammatory changes, development of fluid collections, etc… In the case of resorbable material, reactive synovitis in the first months...
following surgery is not an unusual finding. Bone resorption leading to the appearance of large cysts may also occur during incorporation.

COMPLICATIONS AT THE DONOR SITES:

Complications at the donor sites are more frequent in BTB technique (Fig. 22 on page 30) (1, 10). In this technique, common potential complications are pain in the anterior compartment of the knee and patellar tendon degeneration; residual patella baja, patellar tendon rupture and patellar fracture are rare complications (1, 6, 10). Patellar tendinosis is seen on MRI as thickening and increased signal intensity of the tendon, and should not be mistaken with the normal postsurgical findings in the early postoperative period (10).

In the donor site of hamstring tendon grafts, there may be weakness or persistent pain. Muscular atrophy is infrequent. Rupture of the native tendon, generally due to overharvesting, is exceptional (1, 14).

OTHER COMPLICATIONS

The success of a PCL reconstruction depends largely on tunnel positioning, but there are other factors that may contribute to the failure of the procedure. Associated deficiency of other ligaments such as the ACL or posterolateral corner structures cause instability that would derive in the failure of the PCL reconstruction and progression of osteoarthritic changes (5). An underlying varus malalignment may also contribute to failure of the plasty (5).

The presence of intraarticular loose bodies due to chondral lesions or meniscal fragments may limit knee flexion-extension and produce blocking.

Obviously, in PCL reconstructions complications general for any articular surgery may also occur (6): reactive synovitis, septic arthritis, deep venous thrombosis, etc… which are not of particular interest in this paper.

Images for this section:
**Fig. 1:** Schematic representation of the insertion sites of the native PCL in the femur and tibia. (A) Sagittal image of the femur at the intercondylar notch and (B) tibial plateau.

**Fig. 2:** Tibial fixation techniques. (A) and (B) Tibial inlay. (C) and (D) Transibial tunnel.

**Fig. 2:** Tibial fixation techniques.
**Fig. 3:** Single and double-bundle techniques.

(A) Coronal and (B) sagittal images in a single-bundle reconstruction. Note single femoral tunnel.
(C) Coronal and (D) sagittal images of a double-bundle reconstruction, with double femoral tunnel.
Fig. 4: Fixation material.

(A) Sagittal MDCT image with bone plug in the tibial tunnel (arrowhead). (B) MDCT volume-rendering reconstruction with endobuttons (black arrow) and Richardson staples (thick white arrow). (C) CT and (D) MR images with Richardson staples. (E) Endobutton on MDCT. (F) Coronal reformed MDCT image with metallic interference screw (thick black arrow). (G) Resorbable interference screw (thick black arrow). (H) Sagittal MRI PD image with interference screws in the tibial and femoral tunnels (thick black arrows).
Fig. 5: Magnetic susceptibility artifacts due to metallic fixation material.

(A) and (B) PCL reconstruction with transtibial technique. The artifacts produced by the distal fixation staples do not impair the evaluation of the PCL graft.

(C-E) Multiple ligament reconstruction (PCL, ACL and lateral collateral ligament) as well as several rescue surgeries. Artifacts significantly impair the assessment of the ligament grafts.
Figure 6: Age of the graft. MRI sagittal images in a patient with double ligament reconstruction (PCL and ACL).

(A) PD with fat saturation and (B) PD 3 months after surgery. Note the increased signal intensity and slight thickening of the PCL graft (arrowheads).

(C) PD with fat saturation and (D) PD 1.5 years after the surgery. Normalization of the signal intensity with hypointensity throughout the PCL graft can be observed (arrows).
**Fig. 6:** Age of the graft.

**Figure 7:** Types of grafts: Hamstring graft versus BTB graft.

(A-C) Hamstring graft (gracilis and semitendinosus tendons). Linear high signal intensity images can be observed, indicating the presence of fluid between the graft bundles. Arrowheads in (A) axial PD with fat saturation, (B) coronal T2WI with fat saturation, (C) sagittal PD with fat saturation.

(D-F) BTB graft of patellar tendon in a patient with double ligament reconstruction PCL + ACL. The graft shows homogeneous low signal, without high signal linear images. Arrows in (D) PD with fat saturation, (E) coronal T2WI with fat saturation, (C) sagittal PD with fat saturation.

**Fig. 7:** Types of grafts: Hamstring graft versus BTB graft.
Fig. 8: Evaluation method for tunnel positioning with MRI. Tunnels placed within optimal limits.

(A) Axial images, the tibial tunnel opening is immediately medial to the articular midline.
(B) Sagittal images, the femoral tunnel opening is situated in the first quadrant.
(C) In an oblique coronal plane, the ratio between both values is approximately 6:7 mm.

Fig. 9: Wrong tunnel positioning.

(A) Axial image showing tibial tunnel lateral to the articular midline.
(B) Sagittal image shows femoral tunnel with high and posterior insertion, outside zone 1.
(C) Coronal image showing an excessively low femoral tunnel opening.
Fig. 10: Method for assessment of the tunnels with CT. Tunnels located within optimal limits.

(A) Coronal image for evaluation of the tibial tunnel, which falls slightly medial to the articular midline.

(B) Sagittal image for evaluation of the tibial tunnel, which is located in the posterior half of the retrospinous line.

(C) Axial image for assessment of the femoral tunnel (since it is a double-tunnel technique, with this method we can only evaluate the AL tunnel). The AL tunnel opening (arrowhead) is located at 11 o’clock. Note the PM tunnel opening is located at 9:30 o’clock.

(D) Sagittal image for assessment of the femoral AL tunnel, located in the optimal interval, at approximately 10 mm of the articular surface.
**Figure 11:** Wrong position of the tibial tunnel.

Excessivey high position of the tibial tunnel, in the central region of the retrospinal line.
**Fig. 11:** Wrong position of the tibial tunnel.

![Image of incorrect tibial tunnel positioning]

**Figure 12:** Normal findings in the tunnels.

(A) Sagittal and (B) axial PD with fat saturation images demonstrate bone marrow edema surrounding the femoral and tibial tunnels, a normal finding in a patient operated 1 month before.

(C) Coronal CT image, showing absence of corticalization and slight lucency around the tunnel in another patient recently after surgery. There is a resorbable interference screw in the tunnel.

(D) Axial CT image showing slight sclerosis of the wall of the AL femoral tunnel (arrow).

**Fig. 12:** Normal findings in the tunnels.
Figure 13: Donor site of a patellar tendon BTB graft.

(A-C) Axial images axiales of the donor site of the BTB graft. (A) PD with fat saturation showing central defect in the patellar tendon (arrow). (B) T1WI with bone defect in the inferior pole of the patella and (C) bone defect in the tibial tuberosity. (D-F) Acute changes in patients with recent (D) Axial PD image with fat saturation shows slight thickening and increased signal intensity in the patellar tendon, apart from the central defect. (E) Sagittal PD image with fat saturation demonstrates thickening and increased signal intensity of the distal 2/3 of the patellar tendon (arrowhead). (F) Sagittal image with thickening and increased signal intensity in the distal portion of the tendon (arrowhead).

Fig. 13: Donor site of a patellar tendon BTB graft.
**Figure 14:** Donor site of a hamstring graft. PD fat saturated MRI axial images.

(A) and (B) First postsurgical follow-up study (1 month). Small fluid laminar collections in the medial region of the knee, around the course of the gracilis and semitendinous tendons. The tendon remnants are markedly thin and show attenuated signal intensity (arrows).

(C) and (D) 8 months after surgery. Resolution of the soft tissue findings in the medial region and restoration of the normal thickness and signal in the donor tendons (arrow heads).

*Fig. 14:* Donor site of a hamstring graft.
Figure 15: Chronic disruption of a PCL graft.

MRI images (A) sagittal fat saturated PD and (B) coronal T2WI with fat saturation.
No graft is identified in the intercondylar region, with presence of fluid in the theoretical course of the graft. As an indirect sign of disruption, there is posterior displacement of the tibial (arrow in (A)).

Fig. 15: Chronic disruption of a PCL graft.
**Figure 16:** MRI in patients with graft laxity.

(A) Sagittal PD image shows buckling of the PCL graft and posterior displacement of the tibia (*arrow*), indicating instability.
(B) Sagittal fat saturated PD image in a patient with instability shows PCL graft with a very vertical course, related with diminished capability to resist posterior tibial translation.

**Fig. 16:** MRI in patients with graft laxity.
Figure 17: PCL graft impingement.

(A-C) Patient with flexion-extension limitation. Sagittal MRI (A) fat-saturated PD, (B) PD and (C) axial fat-saturated PD, showing thickening and increased signal intensity of the interarticular course of the graft (arrows).

(D) and (E) Different patients, both with transtibial technique showing a "killer turn" in the opening of the tibial tunnel (arrowheads) associated with impingement.

Fig. 17: PCL graft impingement.
Fig. 18: Postsurgical arthrofibrosis on MRI.

(A) and (B) Mild arthrofibrosis that may be considered a normal finding in the absence of movement limitation, as in this case. Small hypointense nodule adjacent to the articular opening of the tibial tunnel (arrowheads).

(C) and (D) Patients with flexion-extension limitation and diffuse anterior arthrofibrosis (C) following BTB grafting, and (D) without BTB grafting. Note the spiculated ill-defined mass with low signal intensity in Hoffa's pad (thick arrows).

(E-G) Focal arthrofibrosis. A hypointense nodule surrounding the intercondylar course of the PCL graft may be identified (arrows).

(H)arthroscopy image of the "cylops" (Hoffa's pad).
**Figure 19:** Ganglion cyst on MRI. Patients with hamstring tendon graft.

(A) Axial fat-saturated PD shows fluid collection inside the tibial tunnel (arrowhead).

(B) Oblique sagittal T2WI of the same patient demonstrates the extension of the ganglion cyst (arrowhead) and mild widening of the tunnel.

**Fig. 19:** Ganglion cyst on MRI.

**Figure 20:** Widening of the tibial tunnel. (A) sagittal, (B) coronal and (C) axial MDCT images. Irregularity of the cortical lining of the tunnel (arrow in (B)).

**Fig. 20:** Widening of the tibial tunnel.
Figure 21: Complications with the fixation material.

(A) Axial MRI PD image shows extruded interference screw (arrow) protruding on the soft tissues of the anteromedial region of the knee.
(B) Axial CT image shows superficially placed Richards staple, protruding on the soft tissues adjacent to the extraarticular opening of the tibial tunnel (asterisk).

Fig. 21: Complications with the fixation material.

Figure 22: Complications in the donor site of a patellar tendon BTB graft.

(A) Sagittal PD MR image shows altered signal intensity and mild thickening of the patellar tendon, suggesting tendinopathy, and avulsion of a small bone fragment from the proximal insertion (arrow).
(B) Marked thickening and increased signal intensity in the proximal region of the patellar tendon indicating tendinopathy.
(C) Sagittal CT image shows heterotopic ossified foci in the patellar tendon (arrowhead).

Fig. 22: Complications in the donor site of a patellar tendon BTB graft.
Conclusion

It is important to be acknowledged with the different PCL reconstruction techniques and their normal postsurgical appearance. We must be able to identify signs of graft failure and the factors that may contribute to it, as well as other potential complications. Further studies are required to establish specific criteria por tunnel positioning in PCL reconstructions.

References


Personal Information