



# Posterolateral corner repair and reconstruction: overview of current techniques

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**Abstract:** This manuscript intends to review and discuss the current concepts of posterolateral corner (PLC) repair and reconstruction techniques. There are many different types of repair and reconstruction of the PLC. However, the repairs shall be limited to specific situations and the concept of anatomic reconstructions must be scrutinized, as the indications of these technically demanding procedures. Therefore, this updating study aims to address these topics providing a conceptual approach of PLC techniques, dividing it into three main types: non-anatomic fibular based PLC reconstructions, tibial based two tailed PLC reconstructions non-anatomically reproducing the main PLC structures, and anatomic PLC reconstructions (tibial based two tailed PLC reconstructions anatomically reproducing the main PLC structures). In addition, the authors' preferred anatomic PLC reconstructions are described, either using allografts or autografts.

**Keywords:** Posterolateral corner (PLC); lateral/posterolateral knee ligaments; knee ligaments; multiple ligament injuries; current concepts

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## Introduction

The posterolateral corner (PLC) of the knee is the primary stabilizer to varus and external rotation, and it also acts as a secondary stabilizer to posterior tibial translation. The three main structures of this complex are: the lateral (fibular) collateral ligament (LCL), the popliteofibular ligament (PFL) and the popliteus tendon (PT). PLC knee injuries may lead to chronic pain, instability, and surgical failure of cruciate ligament reconstructions, when not properly addressed, by biomechanical overloading (1-10).

The treatment of PLC knee injuries has always been a challenging topic (4,6,11-15). Due to the low healing

capacity of PLC injuries, surgery is usually indicated in most cases, while the non-operative treatment is reserved for isolated PLC injuries involving minor abnormal varus (up to 5 mm) and/or external rotation laxity (up to 5°).

## Repair versus reconstruction

Repair of the injured structures was historically applied to acute cases; however, due to the higher failure rate in comparison to reconstructions (40% versus 6% in one cohort and 37% versus 9% in another cohort), the end-to-end isolated midsubstance repair is not currently recommended (16,17). Although this type of repair can still



**Figure 1** Reattachment of a fibular head avulsion. (A) Ethibond 2 sutures passing through the proximal structures and predrilled fibular head holes to be used as a transosseous repair; (B) transosseous sutures; (C) reattachment of the avulsion, ideally done with the knee in extension.

be used, it must be augmented by a reconstruction of the injured structures.

Presently, the recommended repairs are the ones involving avulsions, especially of structures torn off the fibular head (like the LCL, the PFL and the biceps tendon) or PT, that shall be reattached to the bone, and the ones involving the capsule and the lateral meniscocapsular ligaments that are anchored and sutured to the underlying bone (18). Repair of bone avulsions have a better healing potential than soft tissue avulsions and must be reattached to its insertion site.

### Acute cases surgical treatment

Acute treated cases should have a mean time to surgery of <4 weeks. Acute treated cases tend to obtain better results than chronic ones, so the surgical treatment, ideally, should not be delayed more than 10 days to allow some soft tissue and capsule healing, lowering the risk of fluid extravasation during arthroscopy to address concomitant cruciate injuries. In such cases, some arthroscopy steps should be performed “dry” (without saline, just using the camera visualization). These cautions are intended to avoid compartment syndrome (4,13,14).

It is easier to identify the remnants of the torn structures in the acute setting in comparison to the chronic one because there is no important scar tissue formation. This identification is important, as the treatment of choice for acute PLC lesions involves the repair of avulsions of the PLC structures (fibular head, PT, lateral capsule, lateral meniscocapsular ligaments) reattaching them to its anatomical site (*Figure 1*) combined with the reconstruction of midsubstance tears of these injured structures. This hybrid approach, involving repair and reconstruction, is related to improve subjective outcomes and objective stability (14,18).

### Chronic cases surgical treatment

Chronic PLC injured patients must first be evaluated for lower limb alignment with a full-length lower limb radiography. A proximal tibial opening-wedge corrective osteotomy must be considered if the lower limb mechanical axis (a line from the center of the femoral head to the center of the ankle mortise) passes medial to the apex of the medial tibial eminence and is mandatory if the patient presents double or triple varus (19,20). The weight-bearing axis must be corrected to neutral. If the patient continues to have symptoms of instability at a minimum of three months after the osteotomy site had healed, it is performed a PLC reconstruction combined with anterior cruciate ligament (ACL) reconstruction or posterior cruciate ligament (PCL) reconstruction or both (14,20,21). Interestingly, 38% of the patients do not have symptoms of instability after the realignment osteotomy and do not require ligament reconstructions (20).

In the chronic setting, PLC injuries in patients with neutral or valgus alignment are addressed by reconstruction (4,6,14,15,21,22).

### Types of reconstruction

After some studies demonstrated a high failure rate with primary repair, a trend toward reconstruction of the PLC has occurred (16,17). Early reconstruction techniques for PLC injuries applied a single femoral fixation site and a fibular sling (23). This technique evolved to two femoral tunnels with a fibular sling attempting to better reproduce the anatomy of the PLC (24). Both reconstructions reproduce just two of the three main structures of the PLC, the LCL and the PFL. Biomechanical studies comparing them showed improved results favoring the more anatomic two femoral tunnels reconstruction (25,26). An interesting

**Table 1** PLC reconstruction techniques

Non-anatomic fibular based PLC reconstructions	Tibial based two tailed PLC reconstructions non-anatomically reproducing LCL, PFL and PT	Anatomic PLC reconstructions (tibial based two tailed PLC reconstructions anatomically reproducing LCL, PFL and PT)
Fanelli & Larson, 2002 (23)	Kim <i>et al.</i> , 2004 (35)	LaPrade <i>et al.</i> , 2004 (2)
Bicos & Arciero, 2006 (24)	Stannard <i>et al.</i> , 2005 (33)	Yoon <i>et al.</i> , 2006 (5)
Niki <i>et al.</i> , 2012 (34)	Angelini <i>et al.</i> , 2013 (27)	Stannard <i>et al.</i> , 2015 (29)
Sanders <i>et al.</i> , 2018 (32)		Franciozi <i>et al.</i> , 2018 (6)

PLC, posterolateral corner; LCL, lateral (fibular) collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

**Table 2** Anatomic PLC reconstructions (tibial based two tailed PLC reconstructions anatomically reproducing LCL, PFL and PT) and required graft type

Anatomic PLC reconstructions (tibial based two tailed PLC reconstructions anatomically reproducing LCL, PFL and PT)	Required graft
LaPrade <i>et al.</i> , 2004 (2)	Allograft: Achilles tendon
Yoon <i>et al.</i> , 2006 (5)	Allograft: Achilles tendon
Stannard <i>et al.</i> , 2015 (29)	Allografts: two of the following: semitendinosus or gracilis or anterior tibialis
Franciozi <i>et al.</i> , 2018 (6)	Autografts: semitendinosus + gracilis + posterior 1/2 biceps (if necessary)

PLC, posterolateral corner; LCL, lateral (fibular) collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

**Table 3** Indications for an anatomic PLC reconstruction

Important knee hyperextension
Important external rotation-recurvatum
Proximal tibio-fibular instability
Concomitant posterior cruciate ligament injury
PLC, posterolateral corner.

technique, derived from the single femoral fixation site technique, despite being non-anatomic, is worth mentioning as it allows the combined reconstruction of the ACL and PLC with a single femoral tunnel (27,28).

LaPrade *et al.*, in 2004, introduced the term anatomical reconstruction of the PLC of the knee, based on previous anatomic and biomechanical testing, surgically reproducing the three main structures of this complex: the LCL, the PFL and the PT (2). Based on this biomechanical validated data, the authors believe the term anatomical PLC reconstruction should be reserved for the techniques reproducing the three main structures of the PLC and its anatomic footprints (2,5,6,29). In addition, it has been demonstrated that an anatomic PLC reconstruction requires a PFL reconstruction through a tibial tunnel (30). Consequently, the term non-

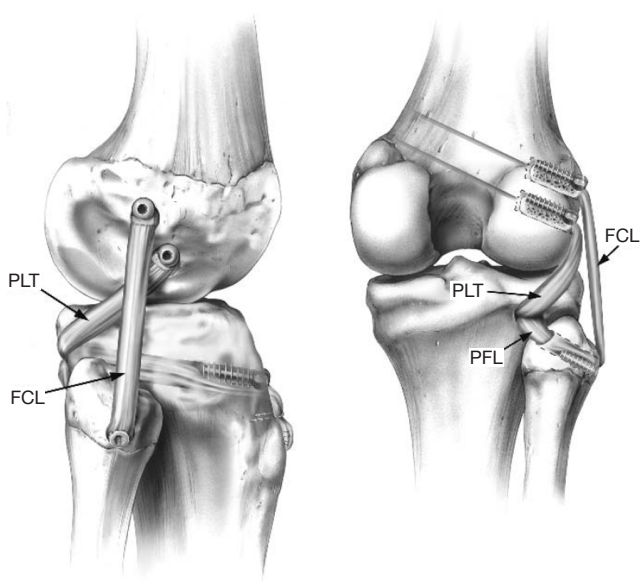
anatomical, should be applied to the techniques that do not reproduce the aforementioned three main structures and also for the techniques that try to reproduce them non-anatomically by single femoral fixation site or other non-anatomic attachments (23,24,27,31-35) (Tables 1,2).

Despite a majority of studies presenting similar results comparing non-anatomic to anatomic PLC reconstructions, it is important to note that some biomechanical and clinical studies present superior results favoring anatomical PLC reconstructions (3,30,31,36-38). Also, certain conditions, such as concurrent proximal tibiofibular instability or an asymmetric knee hyperextension are relative contraindications to non-anatomic fibular based PLC reconstructions requiring a more anatomic tibial based two tailed PLC reconstruction that is a technique which relies both on a fibular head and a tibial tunnel (1,6).

Regarding the biomechanical superiority and rational, the authors believe some conditions are indicative of an anatomic reconstruction over a non-anatomic one (6) (Table 3).

## PLC

Most of the validated PLC reconstructions that intend to reproduce its three main structures rely on allografts or



**Figure 2** LaPrade anatomic PLC reconstruction with Achilles allograft. (A) Lateral view, right knee; (B) posterior view, right knee. From reference (2). PLC, posterolateral corner; PLT, popliteus tendon; FCL, fibular collateral ligament; PFL, popliteofibular ligament.

have to harvest the semitendinosus from both knees due to graft length issues (2,5,27,29,33,35). The authors, when allografts are available, prefer to use the LaPrade *et al.*, 2004 technique as it is biomechanically validated and has improved clinical outcomes reported (21,30) (*Figure 2*).

In the setting of unavailable allografts, the first author has preference to use the Franciozi *et al.*, 2018 technique as it anatomically reproduces the three main structures of the posterolateral aspect of the knee using autografts. This technique provides anatomical PLC reconstruction using autografts as the semitendinosus graft is artificially lengthened by the loop of the suspensory fixation device, surpassing the need of longer allografts to do so (6). It relies just on a semitendinosus and a gracilis autografts, augmented by the posterior half of the biceps, when necessary, avoiding the need of contra-lateral side knee autografts. This technique is an important new resource because Tissue Banks are not available in some countries and regions, in addition to allograft cost issues. Also, this technique had successful improved subjective outcomes and restored objective stability in varus, external rotation and recurvatum in knees with a chronic PLC injury (unpublished data) (*Figure 3*, *Table 4*).

The presented modified LaPrade technique, despite the

similarities with the original, has some important issues to be addressed. The first one is related to the femoral tunnels. Because they are not blind holes, the chances of tunnel confluence are higher, mainly with combined ACL procedures and a 0–20° anterior and 20–35° proximal orientation of the LCL femoral insertion tunnel, in addition to a 20–35° anterior and 0–30° proximal orientation of the PT femoral insertion must be respected (11,12,39-41) (*Table 5*). The next issue is the biceps augmentation in the scenario of a fibular tip avulsion where the reinsertion must be resistant and reliable in order to use this augmentation, being recommended strong fixation in full extension with anchors or through a bone tunnel, similar to a cerclage, distal to the fibular tunnel intended for graft passage.

### Tips to improve plc surgical treatment outcomes

The authors recommend that an anatomic PLC knee reconstruction shall be performed in patients with PLC injury to best improve clinical and functional outcomes, especially in the setting of grade III PLC injuries (6,14,15,21).

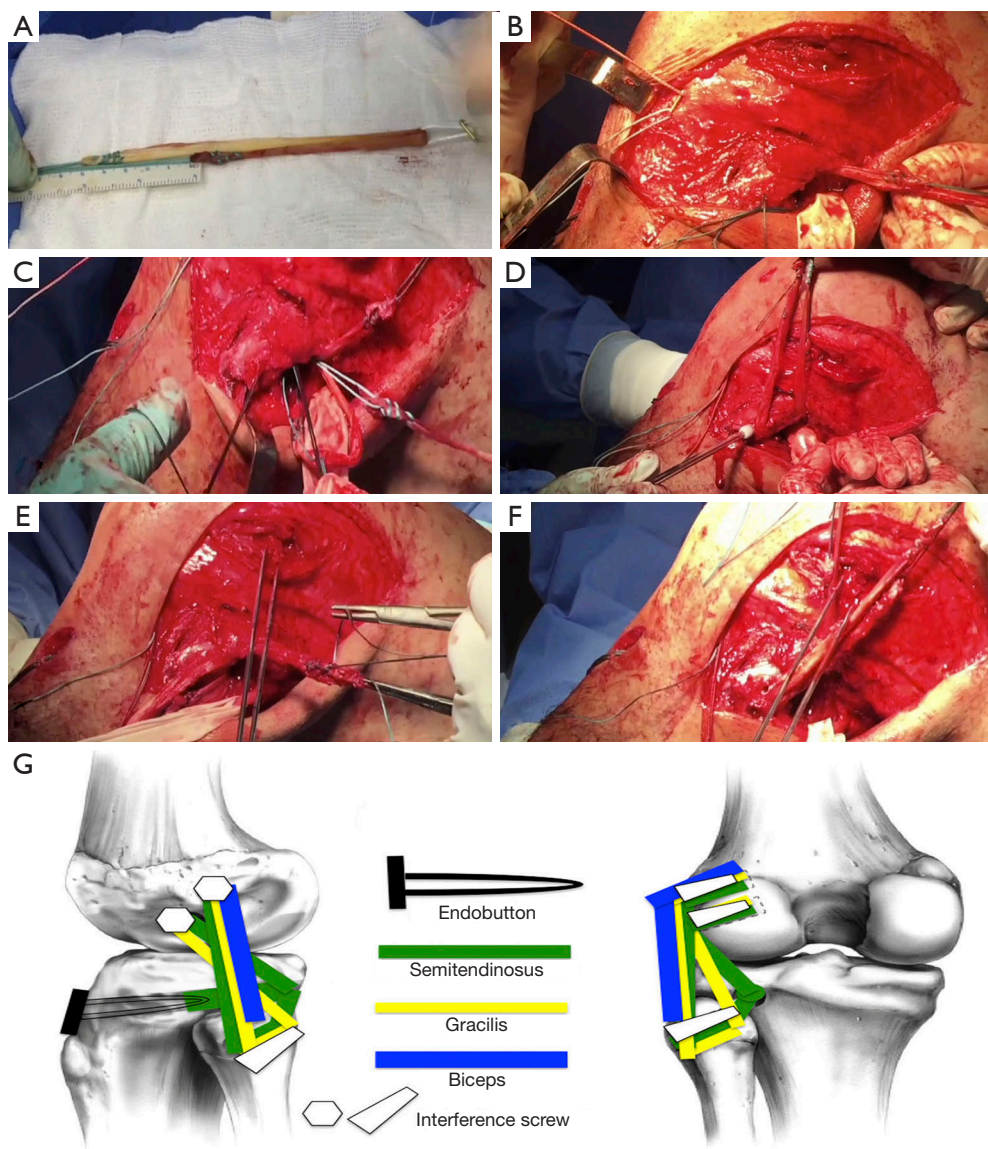
Since identification and graduation of PLC injuries can be tricky, especially at the multiple ligament injured knee, stress X-rays are an objective and reliable method to help objectively assess these injuries (42,43).

PLC injuries are frequently associated with PCL injuries. The treatment of one influences over another as both structures act as secondary stabilizers to each other. In order to optimize surgical results, the surgeon should perform a double bundle PCL reconstruction due to its biomechanical advantage over PCL single bundle reconstruction (44). To do so, access to sufficient and adequate grafts to address all the ligament injuries is necessary as well as proficiency in multi-ligament knee surgeries, as this technique is more demanding than single bundle PCL reconstruction.

If the surgeon intends to perform a concomitant single bundle PCL reconstruction, a lateral tibial tunnel entry point can be utilized instead the medial tibial tunnel entry point as it is more effective to resist posterior translation and safer to avoid popliteal artery injury (45,46).

### Graft tensioning and fixation sequence

Restoring the native tibiofemoral orientation and associated knee kinematics in the setting of a multiple knee ligaments reconstruction is a current hot topic involving knee dislocations. In a one-stage ACL and PCL reconstruction,



**Figure 3** Franciozi anatomic PLC reconstruction with autografts. (A) In order to have one strand 4–5 cm longer than the other, the semitendinosus tendon is mounted asymmetrically into the Endobutton; the bulkiest end of the semitendinosus is set to be the shortest strand. (B) The folded semitendinosus graft is passed from anterior to posterior at the 7 mm tibial tunnel and is secured anteriorly by the suspensory fixation. (C) The longest semitendinosus strand and the gracilis are passed along the fibular tunnel from posterior to anterior; the gracilis will be positioned “U” shaped at the fibular tunnel at the same manner as the fibular based techniques having one anterior strand and one posterior strand around the fibular head. (D) A 7 mm interference screw is introduced at the fibular tunnel while the grafts are tensioned. (E) A strip from the posterior half of the biceps tendon, 1–1.5 cm wide by 5–7 cm long, is prepared splitting the biceps tendon and proximally detaching it. (F) Final configuration, after grafts passage through the third layer: the longest semitendinosus strand in addition to the anterior gracilis strand and the biceps strip reproduce the LCL (tensioned and fixed at 30°, neutral rotation of the leg, and with a valgus reduction force); the shortest and bulkiest semitendinosus strand reproduces the PT; the tibiofibular connecting part of the longest semitendinosus strand and the posterior gracilis strand reproduces the PFL (the grafts reproducing the PT and the PFL are tensioned and fixed at 60°). (G) Lateral and posterior view, left knee; LCL is reproduced by one strand of the semitendinosus, one strand of the gracilis and the biceps; PFL is reproduced by one strand of the semitendinosus connecting tibia to fibula and one strand of the gracilis from the fibula to the PT femoral insertion; PT is reproduced by the bulkiest strand of the semitendinosus. PLC, posterolateral corner; LCL, lateral (fibular) collateral ligament; PFL, popliteofibular ligament; PT, popliteus tendon.

**Table 4** Anatomic PLC reconstruction with autografts (6 demographics presenting mean and range values (unpublished data)

Variables	Pre-operatively	Post-operatively
Patients	33	29 [23 male/6 female]
Age in years [range]	27.6 [20–41]	–
Follow-up in months [range]	–	31.9 [24–59]
Time to surgery in months [range]	8.8 [1.5–60]	–
Varus stress X-ray in millimeters [range]	7.1 [3–13]	1.8 [–2–6], 1 failure
Lysholm [range]	49.7 [25–73]	81.2 [48–100]
IKDC [range]	36.7 [22–63]	70.4 [35–100]

PLC, posterolateral corner.

**Table 5** PLC recommended femoral tunnels orientation to avoid ACL tunnel confluence

Reference	LCL		PT	
	Coronal	Axial	Coronal	Axial
Camarda <i>et al.</i> , 2011 (11)	0°	20°–40°	–	–
Kim <i>et al.</i> , 2013 (40)	10°	20°	10°	20°
Gelber <i>et al.</i> , 2013 (39)	0°	30°	30°	30°
Gali <i>et al.</i> , 2016 (12)	20°	20°	20°	20°
Moatshe <i>et al.</i> , 2017 (41)	0°	35°	0°	35°

PLC, posterolateral corner; LCL, lateral (fibular) collateral ligament; PT, popliteus tendon.

applying tension to one graft changes the tension of the other and displaces the tibia relative to the femur before and after graft fixation as both graft tensions are interrelated. Mal-positioning of the tibia at the final graft fixation may lead to non-anatomic tibiofemoral orientation and badly influence knee kinematics (47,48).

A recent study evaluating multiple ligament reconstruction in an ACL, PCL and PLC deficient knee, applying manual reduction to obtain the normal step-off position of the tibiofemoral articulation, showed that tensioning the PLC first in a bicruciate knee ligament reconstruction with concurrent PLC reconstruction should be avoided because it significantly increased tibial internal rotation. It recommends that the PCL should be tensioned and fixed first (at 90° for the anterolateral bundle,

reducing the knee manually to the normal step-off position of the tibiofemoral articulation, and at full extension for the posteromedial bundle), followed by the ACL near full extension, and that the PLC should be tensioned last (fixation of the FCL at 30° of knee flexion applying a valgus force, followed by the remaining PLC structures at 60° of flexion and neutral rotation) (48).

Another recent study also evaluated bicruciate ligament reconstruction graft tensioning sequence using a simultaneous tensioning protocol. The simultaneous tensioning protocol was used for graft fixation, in the bicruciate reconstruction, maintaining simultaneous tension to both grafts. Two distinctive graft fixation orders were evaluated: PCL fixation first was compared to ACL fixation first. PCL graft fixation was always accomplished at 90° of flexion and ACL graft fixation at full extension. Applying the simultaneous tensioning protocol, the results were different from the study of Moatshe *et al.*, 2018. The study favored ACL fixation prior to PCL fixation using a simultaneous tensioning protocol (47). Tensioning the ACL first on Moatshe *et al.*, 2018 study increased the risk of tibial posterior subluxation in extension (48). However, this might be avoided if both grafts were tensioned simultaneously due to the checkrein effect of the simultaneously tensioned PCL. The study indicates that graft fixation sequence in a bicruciate lesion, using a simultaneous tensioning protocol, should start with the ACL, in extension, to take advantage of the inherent stability of this position and the checkrein effect of the simultaneously tensioned PCL graft. The tibiofemoral articulation is close to the intact knee tibiofemoral orientation while in extension. Using the simultaneous tensioned PCL graft to avoid posterior subluxation of the tibia will lock the articulation into place by the ACL graft fixation. After that, PCL graft fixation will take place at 90° of knee flexion. The ACL fixed graft will act as a checkrein to avoid overcorrection of the tibial step-off caused by the manually applied anterior drawer, in accordance to the study of Kim *et al.*, 2015 (47,49). This finding is supported by another study showing that full-extension is the most stable position after a complete bicruciate injury (47,50). In the setting of a simultaneous tensioning protocol involving a multiple ligament knee lesion, if the one intends to apply the simultaneous tensioning protocol for PLC multiple ligament lesions, the ACL should be fixed first, followed by the PCL and finally the PLC while maintaining simultaneous tension to all non-fixed grafts.

The best graft tensioning and fixation sequence

comparing manual step-off reduction to simultaneous tensioning has yet to be determined.

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