Pearls and Pitfalls of Single-bundle Transtibial Posterior Cruciate Ligament Reconstruction

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Abstract: Posterior cruciate ligament (PCL) injuries are rare, but they often require reconstruction, especially in the setting of combined ligamentous knee injury. Single-bundle transtibial PCL reconstruction is a technique for restoring this important ligament. However, this procedure is technically demanding, and complications can occur if poor techniques are used. This article analyzes the potential pitfalls of this procedure and presents the pearls that may ease the technical demands and reduce the risk of avoidable complications.

Posterior cruciate ligament (PCL) injuries are rare and typically occur in the setting of high-energy trauma or in contact sports. They are usually associated with a combined ligamentous injury but can occur in isolation in rare circumstances. Because these injuries are rare, the current literature lacks appropriately powered studies exploring operative vs nonoperative management or a superior operative technique.

Although surgical indications are controversial, nonoperative treatment may be inappropriately chosen on the part of the treating physician due to the technical demands of surgery, which include navigating the “killer turn” in a transtibial technique. In addition, operative treatment has associated complications, including neurovascular injury, osteonecrosis, fracture, motion loss, residual posterior laxity, anterior knee pain, heterotopic ossification, and compartment syndrome. This article describes the technical pearls and pitfalls of single-bundle transtibial PCL reconstruction in an attempt to reduce the risk of avoidable complications and facilitate the operative procedure to optimize outcome.

**Graft Selection**

The most appropriate graft choice for PCL reconstruction remains controversial because no ideal graft exists to replace this large ligament with large-footprint bony insertion-site anatomy. Hoher et al defined an ideal graft for PCL reconstruction as having the following properties: structural properties identical to an intact PCL; identical geometric shape; no harvest-site morbidity; easy graft passage; secure fixation in an anatomic position; and fast graft incorporation. Autografts and allografts have been used in PCL reconstruction, and each has advantages and disadvantages.

Commonly used autografts in PCL surgery include bone–patellar tendon–bone (BPB), quadriceps tendon, and hamstring tendon. These grafts are readily available and have no risk of rejection or disease transmission, but they have limitations in graft size, prolonged operative times, and donor-site morbidity related to the harvest. Hoher et al recommended that grafts be a minimum of 8 to 10 cm in length to allow for the intra-articular distance the graft must transverse and leave adequate graft for fixation. Although the commonly used autografts typically meet this length requirement, some smaller patients may provide smaller grafts.

Allografts have the advantages of no donor-site morbidity and extensive variation in graft size and length. However, they are expensive and carry the risk of disease transmission and rejection. Commonly used allograft tissues include BPB, Achilles tendon, and
anterior and posterior tibialis tendons.

In a systematic review, Kim et al reviewed the results of 10 clinical studies using the single-bundle transtibial PCL reconstruction technique. They found that autografts are being used more commonly than allografts (78% vs 22%, respectively). The most commonly used autografts were hamstrings tendon and BPB, and the most commonly used allograft was the Achilles tendon. Although various graft types were used, they were unable to correlate the type of graft or fixation to the outcome because of the small patient numbers in these studies.7

In an attempt to identify graft failure and anteroposterior tibial translation of various graft choices, Chen et al8 studied the fixation strength of BPB autograft, quadrupled hamstrings autograft, and Achilles tendon allograft in PCL reconstruction in a cadaveric biomechanical study. They demonstrated that the hamstrings had the maximal failure load but the greatest translation, the BPB had the least translation but less ultimate failure load, and all had the same stiffness that was less than a normal PCL.8

To our knowledge, only 1 prospective clinical study compared autografts to allografts in PCL reconstructions.9 In this study of 55 patients with an average 34 months of follow-up, Wang et al9 found no statistical difference in ligament laxity or radiographic, clinical, or functional outcomes. However, 7 donor-site complications occurred in the autogenous group vs 0 in the allograft group. Because a superior graft has yet to be determined for PCL reconstruction, it remains each surgeon’s preference. Because of the low complication profile, shorter operative time, and large size, we prefer to use an Achilles tendon allograft in our PCL reconstructions.

POSITIONING
A standard leg holder is used with the knee easily flexed at 90º for the majority of patients. A tourniquet is placed high on the operative thigh, and the patient’s gluteal fold is brought to the end of the bed. The nonoperative leg is placed in a padded well-leg holder in the lithotomy position. This position allows the surgeon and assistants adequate space to perform surgery and use fluoroscopy if desired.

The operative leg is placed into an arthroscopic leg holder at the level of the thigh turniquet and adjusted so that the femur is parallel to the floor. The entire extremity is prepped from the holder to the toes. A stockinet is placed over the foot and distal leg and secured with an elastic bandage. A sterile U-drape is placed around the thigh, and a standard arthroscopic lower extremity drape is used.

PORTALS
The arthroscopic portals used in our PCL reconstruction are easily made and fairly standard. We begin by establishing a high and tight anterolateral portal. A low and tight anteromedial portal is established under direct visualization using an 18-gauge spinal needle and an 11 blade. The correct location for this portal is in line with the anterior cruciate ligament (ACL) and just above the intermeniscal ligament.

We use a posteromedial portal in our reconstructions either as a viewing or working portal, depending on the portion of the case. To make this portal, the arthroscope is placed into the Gillquist position, which is through the intercondylar notch below the PCL and over the posterior horn of the medial meniscus.10 Visualization while making this portal is improved by using a 70º arthroscope. Failure to use a 70º arthroscope can lead to poor placement of the portal and poor visualization of the tibial insertion site, which can lead to nonanatomical graft placement and neurovascular injuries during tibial tunnel drilling.

The portal is made as superior and posterior as possible. The portal is a minimum of 2 cm above the joint line and must be posterior to the condyle (Figure 1). This allows one to easily work on the tibial insertion site with instruments inserted via this portal. External landmarks can be used to find the starting point for the portal. The soft spot is located between the femoral condyle and proximal tibia and bounded by the medial head of the gastrocnemius, the semimembranosus, and the medial collateral ligament posteriorly.

In a cadaveric study, McGinnis et al11 described an intra-articular safe zone to prevent saphenous vein and nerve injuries by establishing the portal using intra-articular landmarks. They found the safe area to be superior and posterior to the equator of the medial femoral condyle and bound by the capsular folds.11 The portal is made by localizing this area with an 18-gauge spinal needle, incising the skin, and enlarging the portal with a hemostat. A threaded cannula is then introduced.

The final portal is a low and tight anterolateral portal used to create the femoral tunnel. This is localized with an 18-gauge needle and is made so the femoral tunnel can be created as far anterior and superior on the medial wall as possible. Using these portals, we find that we have adequate visualization and working portals to allow a safe reconstruction. This surgery should only be performed with 30º and 70º arthroscopes.

TIBIAL TUNNEL
Creating the tibial tunnel in PCL surgery is 1 of the most technically demanding portions of transtibial PCL recon-
struction due to the proximity of neurovascular structures to the PCL insertion. In a cadaveric study during simulated arthroscopic conditions, Cosgarea et al found the mean sagittal distance of the popliteal artery to the mid-PCL footprint was 29.1 mm and to the proximal PCL fovea was 9.7 mm. The distance between the PCL insertion and popliteal artery varies depending on the degree of knee flexion.

Matava et al reported that the mean distance between these 2 sites averaged 7.6 mm in the axial plane and 7.2 mm in the sagittal plane through all degrees of flexion; however, this distance was the greatest at 100° of flexion and measured 9.9 mm in the axial and 9.2 mm in the sagittal planes. These data suggest that the knee should remain in flexion when creating the tunnel to maximize the distance between the 2 structures.

Regardless of knee flexion, poor technique and inadequate visualization place the popliteal artery at risk. Various techniques have been described to potentially prevent this complication. Ahn et al described a technique of performing a limited posterior capsular release to increase the distance between the PCL insertion and the popliteal artery. They found that by using this technique, the mean distance from the PCL insertion and midsubstance PCL to the popliteal artery significantly increased by 10.3 and 6.3 mm, respectively. Fanelli et al described a safety incision approximately 1.5 to 2.0 cm in length developing an interval between the medial head of the gastrocnemius muscle and the posterior capsule of the knee joint. This technique allows the surgeon to monitor surgical instrumentation and protect the neurovascular bundle.

To protect the neurovascular bundle, we use several simple techniques during our tibial tunnel creation. Adequate visualization is critical during this portion of the procedure. To obtain this, we perform a low medial wall notchplasty, allowing easy passage of the arthroscope into the Gillquist position. We also recommend using a 70° arthroscope in this position to provide visualization of the posterior compartment of the knee (Figure 2). By staying anterior to our PCL stump, we are protected from inadvertent popliteal artery injury.

As we previously described, the medial meniscal root is identified as a landmark for PCL tibial tunnel placement. A PCL guide is set as vertical as possible to decrease the angle of the “killer turn” and is placed on the PCL footprint under direct visualization. The guide pin is advanced using power initially but then is gently tapped out by hand under visualization. An assistant holds the guide pin with a pituitary forcep from the posteromedial portal to prevent advancement. The tunnel is then reamed on power until fat droplets are seen, after which the tunnel is finished by hand. The anterior tunnel edge is then smoothed with a shaver.

**Femoral Tunnel**

The PCL consists of an anterolateral and a posteromedial bundle. In single-bundle PCL reconstructions, the anterolateral bundle is typically reconstructed due to its favorable biomechanical properties. Race and Amis performed a cadaveric study of the mechanical properties of the PCL and found that the anterolateral bundle was 6 times as strong as the posteromedial bundle. Markolf et al performed a biomechanical study of anterolateral, central, and posteromedial femoral tunnels. The anterolateral bundle reproduced normal PCL force profiles, but the knee was more lax than normal between 0° and 45° of flexion. The central tunnel best matched intact laxities but caused higher graft forces between 0° and 45°. The posteromedial tunnel overconstrained the knee between 0° and 45° and generated high graft forces. They concluded that the posteromedial bundle should not be used for single-bundle reconstructions.

The femoral tunnel may be created in an outside-in or inside-out manner. Using an outside-in technique, a second incision is made medially over the medial femoral condyle, and the vastus medialis is split. With this technique, the angle between the graft and tunnel is more favorable compared with the inside-out technique, which leads to a more acute graft angle and potential graft abrasion. Handy et al termed this the “critical corner,” and in their cadaveric study they found that the
outside-in technique creates significantly lower graft/femoral tunnel angles compared with an inside-out technique. They recommended using the outside-in technique because it may translate to lower rates of graft failure.20

To our knowledge, only 1 clinical study examined the results of both techniques. Kim et al21 compared the results of 1- and 2-incision techniques and found comparable results between the 2 groups 3 years postoperatively.

We create our femoral tunnel using an inside-out technique. As described previously, we establish a low anterolateral portal for tunnel placement using an 18-gauge needle. The portal is made such that the femoral tunnel can be made as far anterior and superior as possible, recreating the anterolateral bundle (Figure 3). The posterior edge of the aperture is smoothed with a shaver to prevent a potential sharp edge, which could cause graft abrasion.

**Graft Passage**

Graft passage remains 1 of the most challenging aspects of transtibial PCL reconstruction due to the sharp angle the graft must transverse after exiting the tibial tunnel and has been given the ominous term “killer turn.” Not only does this turn create difficulty during graft passage, it may also cause abnormal stress on the graft, leading to graft failure with cyclic loading.22,23

In an effort to eliminate the potential graft complications caused by this acute turn, the tibial inlay technique was described by Berg.24 In this technique, the graft is fixated to the tibia PCL footprint using a posterior arthrotomy rather than a bone tunnel.

In a biomechanical cadaver study, Markolf et al25 cyclically loaded transtibial and tibial inlay grafts. They found that the inlay technique was superior with respect to graft failure, graft thinning, and permanent increase in graft length.23 Although biomechanical studies seem to suggest that inlay techniques are superior by avoiding the killer turn, clinical studies have yet to show a clear difference.25,26

When a transtibial surgery is performed, certain techniques may be used to create a more obtuse killer turn and thus ease graft passage. One of these techniques uses an anterolateral tibial tunnel to decrease the angle of the killer turn. Ohkoshi et al27 suggested a tibial tunnel with an entry point under the lateral tibial subcondylar flare approximately 1 to 2 cm anterior to the posterior cortex and 4 cm distal to the joint surface. Using this entry point and an anterograde drilling technique from within the notch, 20 of 21 patients with a 1-year minimum follow-up had mean anteroposterior translation of 2.8 mm and normal or nearly normal International Knee Documentation Committee scores.27

Huang et al28 further studied the anterolateral-directed tunnel in a cadaver study comparing graft angulations and joint translation in anterolateral vs anteromedial directed tunnels. They found that the graft angulation was statistically sharper in the anteromedial specimens, but they found no difference with respect to joint translation.28

Kim et al29 performed a biomechanical comparison of 3 tibial tunnel placements: lateral, central, and medial. They demonstrated that the medial approach showed remarkably higher stresses and forces on the interface between the PCL and the killer turn.29 Although these studies show that an anterolateral approach may be superior, further prospective clinical data are needed to validate these results.

Other techniques have been described to ease graft passage. Mariani et al30 described the use of a blunt trochar through the posteromedial portal to act as a pulley while pulling the graft through the tibial tunnel. They found that this avoids impingement of the bone block against the edge of the tibial tunnel and reported success using this technique in >40 cases.30 Van den Broek et al31 used a Deschamp clamp and meniscal repair needle to pass their grafts, which allowed passage without the use of posterior portals and obviated extensive debridement at the tibial insertion.

We create our femoral tunnel from an anteromedial direction. To decrease the angle of the killer turn, we ream the tibial tunnel as vertically as possible. Once the tunnels have been established, the apertures are smoothed with a shaver.

To view graft passage, we place our camera into the Gillquist position through the anterome-

![Figure 3: Femoral tunnel is made as far anterior and superior within the notch, recreating the anterolateral bundle.](image3.png)

![Figure 4: Bioabsorbable interference screw is placed into the tibial tunnel over a wire while under direct visualization.](image4.png)

![Figure 5: Final posterior cruciate ligament viewed anteriorly (A) and posteriorly (B).](image5.png)
Graft fixation

The goal of graft fixation is to provide support to the graft–bone interface until biologic incorporation is complete. Devices used during ACL surgery are commonly adapted for use in PCL reconstruction. However, PCL surgery involves a different direction of bone tunnels, creating acute turns that may make these fixation devices inadequate for PCL surgery.

In their review of graft fixation, Hoher et al used the terms “anatomic” and “extra-anatomic” to describe fixation options. With anatomic fixation, an interference screw is placed into the graft–bone interface within the tunnel. Extra-anatomic fixation includes devices that sit outside the bone, including buttons, screw/washers, and staples. Although the authors outlined these techniques in PCL surgery, they were unable to find literature to support the superiority of a fixation technique.

A more recent concept in PCL tunnel fixation is aperture fixation. As previously discussed, the killer turn can lead to graft failure and thinning and increased graft length in transtibial techniques. Cadaveric studies showed that inlay techniques may eliminate these unwanted effects. Aperture tibial fixation places interference fixation at the intra-articular opening of the tibial tunnel, creating the shortest possible graft. Margheritini et al studied the effects of distal and combined aperture and distal fixation in a biomechanical model. They found significantly less posterior translation and significantly restored knee kinematics with the combined fixation.

Weinmann et al evaluated reducing the killer turn by fixation level and aperture smoothing. They cyclically loaded reconstructed PCL grafts in a porcine tibia model fixed extracortically or with aperture fixation and with sharp or smoothed tunnel edges. Their results suggest that rounded tunnel edges lead to significantly less graft damage compared with sharp edges. In addition, they found superior results of aperture fixation compared with extracortical fixation.

The clinical results of aperture fixation have been promising but consist of case series with small numbers. Herman et al reconstructed the anterolateral bundle in 25 patients with PCL instability and pain using BBP autograft, hamstrings autograft, or Achilles allograft using interference screw fixation at the tunnel aperture. They reported good functional outcomes and a mean anteroposterior laxity difference of 2.1 mm between knees measured by KT-1000 (MEDmetric, San Diego, California) at 6- to 12-year follow-up.

Gill et al evaluated the results of aperture fixation using combined distal and proximal interference screws. In their small series of 10 patients with a minimum 1-year follow-up, they found improvement in knee scores and no difference $>5$ mm in anteroposterior displacement from the contralateral knee. This technique can be difficult because it requires the screw to transverse the length of the tunnel without exiting into the joint. In addition, a metal interference screw may become difficult to remove if revision surgery is necessary.

In our technique, we fixate our Achilles allograft into the femoral tunnel with a bioabsorbable interference screw. We use combined aperture and extracortical fixation on the tibial side. For the aperture fixation, we place a bioabsorbable interference screw over a wire while directly visualizing the tibial tunnel (Figure 4). This ensures that the screw is placed at the appropriate level and does not overshoot the tunnel and potentially damage posterior neurovascular structures. The graft is then fixed extracortically with a screw and spiked washer. By using interference screws at the aperture of both tunnels, this effectively improves the biomechanical properties of the graft construct at time zero, particularly stiffness. After fixation, the graft is viewed anteriorly and posteriorly (Figure 5).

REFERENCES


