Surgical Technique

Aperture Fixation in PCL Reconstruction: Applying Biomechanics to Surgery

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Abstract

Background Biomechanical studies suggest reducing the effective graft length during transtibial posterior cruciate ligament (PCL) reconstruction by augmenting the distal tibial fixation with a proximal screw near the tibial tunnel aperture could increase graft stiffness and provide a more stable reconstruction. However, it remains unknown to what extent this mechanical theory influences in vivo graft performance over time.

Surgical Technique We developed a technique to augment tibial distal fixation with a proximal screw near the tibial tunnel aperture to shorten the effective graft length and increase graft stiffness.

Patients and Methods We retrospectively reviewed all 10 patients who had isolated PCL reconstructions with combined distal and proximal tibial fixation from 2003 to 2007. Mean age of the patients was 36.5 years. We measured ROM and obtained Tegner, International Knee Documentation Committee (IKDC), and Lysholm scores. Anteroposterior stability was evaluated with a KT-2000 arthrometer. Minimum followup was 1 year (mean, 2.5 years; range, 1–4.8 years).

Results Mean Tegner scores before injury and at last followup were 7.3 and 6.5, respectively. Mean postoperative IKDC score was 87 versus a preoperative IKDC score of 43. Mean Lysholm score was 89 at last followup. All patients achieved full terminal extension. No patient had greater than a 5-mm difference in anterior or posterior displacement from the contralateral knee as measured by a KT-2000 arthrometer postoperatively (0.93 ± 0.79 mm).

Conclusions In this small series, augmentation of tibial distal fixation with a proximal screw near the tibial tunnel aperture during reconstruction of the isolated PCL rupture restored function, motion, and stability.

Level of Evidence Level IV, therapeutic study. See Guidelines for Authors for a complete description of levels of evidence.

Introduction

The lack of clinical and scientific information and consistent stability, functional level, and ROM after surgical reconstruction of the posterior cruciate ligament (PCL) have contributed to many surgeons recommending non-operative treatment [30]. However, there is growing evidence that rupture of the ligament is not without adverse consequence of the knee as previously believed. Several studies show nonoperative treatment will restore the functional activity level in some individuals with an isolated PCL injury [5, 13, 26, 27]. Other studies suggest patients with more severe (Grade II or III) posterior laxity may experience chronic instability and associated pain [3, 13, 32] and have worse functional scores and increased articular degeneration on radiographic assessment as the time from injury increases [9, 13]. Therefore, it is important to identify in a timely manner those patients in whom

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the injury is likely to result in persistent instability, knee pain, and degenerative arthritis.

For reconstruction to be justifiable, it has to offer better long-term functional outcomes than those obtained by nonoperative treatment. Despite the technique used, current PCL reconstruction methods do not consistently restore posterior tibial translation to that of the contralateral knee [4, 17, 34]. Residual increased posterior translation of the tibia has been documented after traditional transtibial techniques [11, 17, 22, 28], and postoperative stability of the knee and subjective patient outcomes are not improved after alternative approaches such as tibial inlay fixation techniques [14, 18, 19, 21, 24, 31] or double-bundle reconstruction of the PCL [1, 2, 8, 10, 35].

We demonstrated that during transtibial PCL reconstruction, an Achilles tendon allograft fixed at the proximal outlet of the tibial tunnel created the shortest possible effective graft length (the length between its fixation points) [6]. One study suggests reconstructions resulting in a longer effective graft length could result in less stiffness than with a shorter graft [15]. The closer the fixation is located to the ligament insertions, the stiffer the graft will be [6]. We modified our transtibial PCL reconstruction technique to use a proximal screw (aperture fixation) and a traditional distal screw for tibial graft fixation (Fig. 1) to provide a similar effective graft length as that of an inlay graft but without the concerns of increased injury potential to the neurovascular structures during posterior dissection [23] or additional posterior tibial translation secondary to loss of capsular continuity after capsulotomy [25, 29]. A cadaveric study by Margheritini et al. [20] demonstrated that, compared with anterior-only fixation, anterior graft fixation augmented with posterior fixation within the tibial tunnel decreased the effective graft length and increased the stiffness of the PCL graft, resulting in less posterior tibial translation [20]. The increased stiffness with anterior graft fixation was observed at time zero on cadaveric specimens and may not reflect in vivo graft performance over time because factors such as graft healing and postoperative rehabilitation cannot be addressed in vitro.

We describe our surgical technique and to confirm the theoretical advantages of combined distal and proximal tibial fixation, we determined activity level, subjective outcomes scores, ROM, and knee stability in a homogeneous, isolated PCL-deficient population who underwent the surgical reconstruction.

Surgical Technique

With the patient positioned supine on the operating table, we performed an examination under anesthesia. All surgical procedures were performed by a single sports

Fig. 1 Illustration of the combined distal and proximal tibial fixation for posterior cruciate ligament reconstruction. After femoral fixation (a), the graft is secured by a bioabsorbable screw near the aperture of the tibial tunnel (b) augmented with an interference screw (c).

medicine fellowship-trained orthopaedic surgeon (TJG). The amount of posterior drawer, total tibial AP translation, varus/valgus stability, and external rotation and ROM were noted. Reconstruction of the PCL using a combined distal and proximal tibial fixation technique was then performed using an Achilles tendon allograft. We fashioned the Achilles tendon allograft to fit through a 10-mm spacer. The tendinous portion was tubularized with the distal tip of the graft shaped to a 3-mm diameter to facilitate graft passage. The graft was whipstitched with Number 5 fiber wire (Arthrex, Naples, FL, USA) and two Number 2 OrthoCord sutures (Ethicon, Somerville, NH, USA) sutures were placed in the bone block.

We performed a diagnostic arthroscopic procedure to document the status of the menisci, cruciate ligaments, and articular cartilage. The PCL remnants were then débrided from anterior to posterior on the lateral aspect of the medial femoral condyle (note: visualization of fat indicates the proximity of the vascular bundle). We left a portion of the native ligament attached to the femoral attachment site. Next, an accessory posteromedial portal was established with the extremity in the figure-of-four position and a 70°

arthroscope was used to débride the posterior aspect of the proximal tibia under direct visualization until the fibers of the posterior tibialis were visible.

A PCL tibial guide (Arthrex) was prepared for the creation of the tibial tunnel. We set the depth of the pin on the PCL tibial guide such that the tip of the pin pass-pointed only 1 mm beyond the tip of the PCL guide. While holding the pin in this position, the drill was tightened over the pin flush to the PCL tibial guide such that the pin would traverse only 1 mm beyond the tip of the PCL guide before being blocked by the Jacobs chuck contacting the PCL guide. We do not recommend use of a pin driver; this is to ensure the pin does not inadvertently protrude past the posterior tibial cortex and injure the neurovascular structures in the popliteal fossa.

Using the 70° arthroscope in the anterolateral portal for visualization, we placed the tip of the PCL tibial guide 1 cm distal from the proximal aspect of the posterior tibial plateau located just lateral to midline in the coronal plane in the lateral aspect of the tibial attachment site of the PCL. The slightly lateral position was chosen to better correct the persistent external tibial rotation seen in PCL deficiency [16]. The reamer was then inserted at a 70° angle and a 10-mm tibial tunnel drilled under direct visualization (Fig. 2). Before penetrating the posterior cortex during subsequent drilling, we measured the tibial tunnel length using the markings on the reamer. Typically, this distance is 60 to 65 mm in length. The posterior cortex was then penetrated by hand.

We made a 3-cm longitudinal incision from the superomedial border of the patella and extended it proximally. The vastus medialis obliquus was elevated or split in line with its fibers, and the anteromedial cortex of the distal femur was exposed. We set the PCL femoral guide (Arthrex) to 70° and placed it approximately 6 mm posterior to the articular surface in the 11:00 o'clock position for left knees (1:00 o'clock position for right knees). The extraarticular portion of the PCL femoral guide was positioned halfway between the medial edge of the trochlea and the medial epicondyle and as proximal on the femur as possible to decrease the risk of avascular necrosis of the medial femoral condyle (Fig. 3). An 11-mm femoral tunnel was drilled.

The Achilles tendon allograft was passed in antegrade fashion (Fig. 4). Typically, we used an 8 × 30-mm composite screw (Milagro; DePuy-Mitek, Raynham, MA, USA) to secure the femoral tunnel. Actual screw diameter was determined based on graft-tunnel fit. Cycling of the knee was performed to check on relative graft isometry. All procedures revealed less than 1 to 2 mm of graft motion.

In preparation for the tibial fixation, an assistant held the knee at 90° of flexion while performing an anterior drawer maneuver with a slight valgus force. A depth gauge is used

Fig. 2 Drilling of the tibial tunnel. The drill sleeve for the PCL tibial guide is positioned at the estimated lateral edge of the medial collateral ligament, and drilling is performed until the drill itself is blocked by the PCL tibial guide from advancing further. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

to measure the tibial tunnel, typically 60 to 65 mm. To provide aperture fixation in the tibial tunnel, we placed a mark on the screwdriver after measuring from the tip of the screw shaft that coincided with the measured tibial tunnel length (approximately 60–65 mm; Fig. 5). This assures that the tip of the screw is placed at the posterior cortex of the tibia. A 9 × 30-mm composite proximal screw (Milagro; DePuy-Mitek) was advanced toward the posterior and proximal aspect of the tibial tunnel until the mark on the screwdriver reached the anterior cortex of the tibia (Fig. 6). The proximal screw was placed inferior to the graft to engage the posterior cortex while preventing the graft from folding over the screw. A second 9 × 30-mm titanium interference screw (Guardsman; Conmed-Linvatec, Largo, FL, USA) was stacked more anteriorly and distally in the tunnel to augment the fixation (Fig. 7).

All patients underwent our standard postoperative rehabilitation for these injuries (Table 1). Our standard postoperative rehabilitation protocol consists of five phases to protect the reconstructed ligament and ease patients back to activity with an early emphasis on ROM. Phase 1 is from 0 to 2 weeks and involves partial weightbearing with a

Fig. 3A–C (A) Drilling of the femoral tunnel. The extra-articular portion of the posterior cruciate ligament (PCL) femoral guide should be positioned between the medial edge of the trochlea and the medial epicondyle and also as proximal on the femur as possible to decrease the risk of vascular disruption to the medial condyle. (B) Femoral guide placed 6 mm from the articular cartilage on the medial femoral condyle. (C) View of the femoral tunnel. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

Fig. 4 Antegrade passage of the graft through the knee by pulling on the suture. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

hinged brace locked at 0° with passive knee flexion 0° to 90°. Phase 2 is from 2 to 6 weeks with partial weight-bearing and continued use of the brace for ambulating 0° to 90°. At this phase in the rehabilitation protocol, patients use a continuous passive motion machine for 10 hours a day for Weeks 3 and 4 to gain their full ROM. Phase 3 is 6 to 12 weeks with no brace and full weightbearing. At this point patients should have full ROM. From 0 to 12 weeks patients should focus on closed-chain strengthening and proprioception exercises. Phase 4 is 12 to 18 weeks

Fig. 5 To provide aperture fixation in the tibial tunnel, a mark is placed on the screwdriver shaft that coincides with the measured tibial tunnel length (usually approximately 60–65 mm) by wrapping a SteriStrip around the screwdriver. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

postoperatively with no restrictions on ROM. Patients should continue closed-chain strengthening and start single-leg progression avoiding hamstring resistance. At this point, patients are fitted for a sports brace. Phase 5 is from 18 weeks onward with no restrictions and patients should ease back into their activities slowly starting with the return to run progression (See Appendix 1 for details.

Fig. 6 Proximal fixation in the tibial tunnel with the knee held at 90° of flexion while performing an anterior drawer maneuver with a combined valgus force. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

Fig. 7 Distal fixation in the tibial tunnel with a titanium interference screw. (Reproduced with permission from Oh LS, Gill TJ. Single-bundle posterior cruciate ligament reconstruction: arthroscopic transtibial technique. In: Gill TJ, ed. *Arthroscopic Techniques of the Knee: A Visual Guide*. Thorofare, NJ: Slack Inc; 2009:141–163.)

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Patients and Methods

We retrospectively reviewed all 10 patients who had isolated PCL reconstructions with combined distal and proximal tibial fixation from June 2003 to April 2007. The patients were active on at least a moderate athletic level before injury and had a primary complaint of persistent subjective instability that limited their athletic participation or work. During that same time, we treated 20 patients with PCL ruptures; inclusion criteria were patients with isolated PCL tears and we excluded patients with injury to other ligaments or the capsule, detectable cartilage lesions, and injury to the underlying bone. The indications for reconstruction were (1) with AP instability based on clinical examination (Grade 3 instability, ie, greater than 10 mm increased posterior translation compared with that of the contralateral knee on the posterior drawer test as measured by the senior orthopaedic surgeon (TJG)); (2) isolated, complete PCL rupture documented by MRI; and (3) patients who had pain or instability that did not improve

Table 1. Rehabilitation schedule

Phase: Time period	Activity
One: 0–2 weeks	Partial weightbearing with brace, passive knee flexion 0°–90°
Two: 2–6 weeks	Continuous passive motion (CPM) 10 hours/day for Weeks 3 and 4
Three: 6–12 weeks	No brace and full weightbearing
Four: 12–18 weeks	No restrictions on ROM; begin single-leg progression avoiding hamstring resistance; patients are fitted for sports brace
Five: 18 weeks onward	No restrictions; ease back into activities slowly starting with the return to run progression

with nonoperative treatment (such as bracing and rehabilitation). The contraindications for surgery were patients whose symptoms improved with nonoperative treatment. All data were recorded in a prospective database of patients with isolated PCL injuries. The 10 patients had answered an International Knee Documentation Committee (IKDC) questionnaire [16] before surgery and all patients were invited and available for a followup examination. The

Table 2. Comparison with the literature

Study	Year of study	Diagnosis	Followup (years)	Major findings			Technique used
Hermans et al. [9]	2009	Isolated	9.1	IKDC	65	Anterolateral bundle	
				Lysholm	75		
				VAS	8		
				Tegner	5.7 (preoperative 7.2)		
				KT-1000	2.1 mm		
				Telos	4.7 mm		
Kim et al. [14]	2009	Isolated	2	Mean side-to-side difference in posterior tibial translation: tibial inlay double-bundle (3.6 ± 1.43 mm) transtibial single-bundle group (5.6 ± 2.0 mm).		Tibial inlay versus transtibial	
Bergfeld et al. [2]	2005	Isolated	Cadaveric	No statistical differences in translation between the intact state and reconstructions, between reconstructions at any flexion angle, and no differences in translation between graft options		Single- versus double-bundle tibial inlay	
Wang et al. [35]	2004	Isolated	3.4 (single) 2.3 (double)		Single	Double	Single- versus double-bundle
				VAS	1.47	1.31	
				Lysholm	88	89	
				Tegner	4.5	5.2	
				IKDC			
				Normal	4	8	
				Nearly normal	7	5	
				Abnormal	4	2	
				Severe abnormal	4	1	
Gill et al. (current study)	2011	Isolated	2.5	Tegner	7.3 (preoperative 6.5)		Aperture tibial fixation
				IKDC	87 (preoperative 43)		
				Lysholm	89		
				KT-2000	No patient had > 5 mm difference in anterior or posterior displacement from the contralateral knee as (0.93 mm $\pm$ 0.79 mm)		

IKDC = International Knee Documentation Committee.

mechanism of injury was a sports injury ($n = 7$), a motor vehicle accident ($n = 2$), and unknown ($n = 1$). Three patients with a meniscal injury requiring removal of less than 50% of the medial meniscus were included in the study. Six male and four female patients with a mean age at followup of 36.5 years (range, 23–66 years) made up our study group. The mean $\pm$ SD time between injury and surgery was 3.1 ± 5.5 years (range, 1.5 months to 21 years). Seven of the 10 included patients were included in our previous study of the tibiofemoral and patellofemoral kinematics after reconstruction of an isolated PCL injury [7]. The minimum followup was 1 year (mean, 2.5 years; range, 1.0–4.8 years). The study was approved by the Institutional Review Board, and all patients gave written informed consent to be included.

The preoperative and postoperative functional outcome assessments at minimum 1 year or final study followup were performed using the Tegner activity scale and IKDC 2000 scale [12]; postoperative assessment additionally included the Lysholm score. At 2 weeks postoperatively, patients had radiographs taken. History and physical examination were performed at 6 months and 1 year postoperatively. Postoperative clinical function was evaluated based on knee ROM, anterior and posterior drawer testing, collateral stability testing, reverse pivot shift testing, “dial test,” and side-to-side difference of posterior laxity using an arthrometer (KT-2000; MedMetric, San Diego, CA, USA).

We used a paired Wilcoxon test to detect differences in preoperative and postoperative patient outcome scores and

clinical scores between the involved and noninvolved knee (Stata 11; StataCorp, College Station, TX).

Results

We observed no differences ($p = 0.27$) in activity levels between the mean preinjury and postoperative Tegner activity scale: 7.3 ± 1.6 and 6.5 ± 1.6 before injury and after reconstruction, respectively. The lowest postoperative Tegner score was 5.0, which corresponds with the ability to perform heavy labor and recreational sports. The subjective portion of the IKDC score was improved in all 10 patients. Compared with the mean preoperative IKDC score, the postoperative IKDC score improved (from 43 ± 11 to 87 ± 11 ; $p = 0.018$). At the last postoperative evaluation, the mean postoperative Lysholm score was 89 ± 13 . Stability scored a mean $\pm$ SD of 22 ± 4 out of 25 points in the Lysholm score.

At last followup, there were no differences in ROM between the PCL-reconstructed and contralateral normal knees. Each knee was able to achieve full, terminal extension. Mean $\pm$ SD postoperative flexion in the PCL-reconstructed knees averaged $137^\circ \pm 11^\circ$ versus $138^\circ \pm 9^\circ$ in the contralateral normal knees ($p = 0.42$). Combined anterior and posterior translation was assessed with the knee at 90° of flexion using a KT-2000. With manual maximum testing, the combined difference ($p = 0.38$) in translation of the PCL reconstructed knees was less than 1 mm ($0.93 \text{ mm} \pm 0.79 \text{ mm}$) when compared with the normal contralateral knees. The largest combined difference for a reconstructed knee was 1.99 mm greater than its contralateral knee. All patients had a negative dial test.

No intraoperative or postoperative complications were encountered.

Discussion

According to biomechanical testing of PCL reconstruction in cadaver knees, there might be a theoretical advantage of reducing the effective graft length by augmenting the tibial distal fixation with a proximal screw near the tibial tunnel aperture [15]. The rationale for using this technique in a transtibial tunnel reconstruction of PCL-injured patients was that it would offer an alternative to the need for an inlay or double-bundle technique to achieve knee stability that is comparable to the uninjured knee. We therefore described our surgical technique and to confirm the theoretical advantages of combined distal and proximal tibial fixation, we determined activity level, subjective outcomes scores, ROM, and knee stability in a homogenous, isolated PCL-deficient population who underwent the operation.

We note several limitations in the present study. First, this was a retrospective review of a small number of patients. Isolated PCL tears are less common injuries and it would be difficult to gather enough patients for a comparative study. Second, a historical comparison of our data with those available in the literature is challenging, because numerous surgical variables such as graft tensioning and material, tunnel placement, screw parameters (diameter, length, material), or the position of the screw within the tunnel as well as clinical variables including associated injury at the time of injury or time between injury and surgery [9] could influence the outcome of the procedure. Nonetheless, our observations in these 10 PCL-reconstructed patients after a combined distal and proximal fixation technique compared favorably with the observations by others (Table 2) with no differences in activity level between the preoperative level and postoperatively and no difference in ROM between the PCL-reconstructed and contralateral normal knees. Third, we were unable to isolate the actual effect of a combined distal and proximal fixation from a proximal fixation-only approach on the clinical outcome. Hermans et al. recently published the long-term results (average followup of 9.1 years) of a proximal fixation of the PCL graft with an interference screw in 25 patients (nine treated with bone-patellar tendon-bone autograft, 15 with a semitendinosus gracilis autograft, and one with an Achilles tendon allograft) and found improved subjective patient functional outcomes if no cartilage damage was present at the time of surgery [9]. Fourth, we had a minimum followup time of 1 year and mean of 2.5 years. Although this time period allows meaningful comparison to previously reported studies, long-term followup will be helpful to define knee function after our surgical technique. Finally, static measurement of AP translation through an arthrometer does not always correlate with AP translation measured during physiological loading of the knee [16, 33]. However, the tibiofemoral kinematics of seven of the included patients have been measured as well during weightbearing knee flexion using a combined MR and dual fluoroscopic imaging technique [7]. The combined distal and proximal tibial fixation technique restored the AP tibial translation to levels similar to those of the contralateral knee, indicating the graft fixation indeed provides stable reconstruction during weightbearing flexion.

We found augmenting the tibial distal fixation with a proximal bioabsorbable screw near the tibial tunnel aperture when reconstructing the isolated ruptured PCL restored function, motion, and stability in this small series of patients.

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