



Multiple Looping Technique for Tibial Fixation in Posterior Cruciate Ligament Reconstruction of the Knee

Jung Ho Noh, M.D., Ph.D., Kyoung Ho Yoon, M.D., Ph.D., Sang Jun Song, M.D., Ph.D., Young Hak Roh, M.D., and Jae Woo Lee, M.D.

Abstract: The outcomes of posterior cruciate ligament reconstruction may be negatively affected by insufficient tibial tunnel fixation due to relatively lower bone density of the proximal tibia. We introduce a new technique of tibial fixation for posterior cruciate ligament reconstruction using free tendon Achilles allograft that is less affected by the bone density of the tibial metaphysis.

The posterior cruciate ligament (PCL) is one of the primary stabilizers of the knee and is the main restraint against posterior tibial translation. The PCL generally heals well with conservative treatment when it is stretched or even ruptured.¹⁻³ When the PCL has not healed and shows significant posterior laxity, reconstruction has to be considered to re-create normal knee kinematics to restore joint function and thus to prevent excessive stress on the articular cartilage, especially in the patellofemoral and medial tibiofemoral articulation, resulting in osteoarthritis.⁴⁻⁸ Although reconstruction is the treatment of choice in case with failure of conservative treatment, clinical outcomes have not been as predictable as those of anterior cruciate ligament (ACL) reconstruction.

Several types of autografts and allografts have been introduced for PCL reconstruction, and allogeneic Achilles tendon is the most popular graft because the

Achilles allograft is relatively longer and larger than other grafts and there are more available options in surgical techniques for PCL reconstruction.⁹⁻¹² When the Achilles allograft is used, it usually has a bone block on one end and is fixed with metallic or bioabsorbable interference screws. Bone-to-bone fixation has been shown to be more stable than soft tissue-to-bone fixation.^{13,14} However, the fresh-frozen Achilles allografts in the Republic of Korea are mostly imported from overseas, and they are not so “fresh” and their bone blocks are too hard. Whether the end with the bone block is fixed in the femoral or tibial tunnel, the bone block sometimes cracks during fixation with interference screws or pre-tensioning with cyclic range of motion, which may cause loosening and residual laxity. Moreover, the thickness of the bone block is greater than that of the tendinous portion, so the diameter of the tunnels has to be much larger compared with the thickness of the tendinous portion of the graft, which is not desirable when considering revision. In addition, the tibial metaphysis is relatively weak for fixation of the graft in the tunnel with interference screws using a transtibial technique. Using soft-tissue graft, tibial fixation has been challenging because of the relatively lower density of the proximal tibia. We introduce a new fixation technique using free tendon Achilles allograft that is less affected by the bone density of the tibial metaphysis.

Surgical Technique

A remnant was preserved in all the operations. The diameter of each femoral and tibial tunnel was 10 mm. The tibial tunnel was made at the footprint with an

From the Department of Orthopaedic Surgery, Graduate School of Medicine, Kangwon National University (J.H.N., J.W.L.), Chuncheon; Department of Orthopaedic Surgery, Kyunghee University School of Medicine (K.H.Y., S.J.S.), Seoul; and Department of Orthopaedic Surgery, Gachon University School of Medicine (Y.H.R.), Incheon, Republic of Korea.

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Address correspondence to Young Hak Roh, M.D., Department of Orthopaedic Surgery Gil Medical Center, Gachon University School of Medicine, 1198, Kuwol-dong, Namdong-gu, Incheon 405-760, Republic of Korea.

E-mail: coolman02@naver.com

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angle of 45° to the tibial shaft. The superior rim of the intra-articular aperture of the tibial tunnel was rasped to blunt the sharp edge. The femoral tunnel was made at the footprint of the anterolateral bundle or the 1- or 11-o'clock position through an anterolateral portal with knee flexion of 90°. The tunnel was made to be 30 to 35 mm long using an inside-out technique, and the rest of the tunnel was created with a 4.5-mm reamer.

Fresh-frozen Achilles allograft was thawed at room temperature. Its length should be 20 cm or more. The length of the allograft was labeled on the package. The calcaneal bone block was removed with the attached tendon saved. It is usually separated by manual tension without difficulty. The tendon was looped to create a 2-strand graft, and it was trimmed to be 10 mm thick. After the thickness of the graft was adjusted, the graft was looped over the Ligament Washer (Solco, Pyeongtaek, Republic of Korea) to create 2 strands (Fig 1). The length of the 2-strand graft was set to be 11 to 11.5 cm. About 30 mm of each free end of the tendon graft was sutured in whipstitch fashion with 2 strings of No. 2 FiberWire (Arthrex, Naples, FL). About 20 mm of the looped end was whipstitched with No. 2 Ethibond (Ethicon, Somerville, NJ). The free ends of the graft were inserted into the femoral tunnel through the anterolateral portal and tied to a 15-mm Suture Washer (Smith & Nephew, Andover, MA) on the outer cortex of the medial femoral condyle with a total of 4 pairs of tethering sutures of No. 2 FiberWire (Video 1). The looped end was inserted into the tibial tunnel through the anterolateral portal using 2 leading sutures of No. 2 Ethibond slung over the Ligament Washer in case of suture breakage during insertion of the graft into the tibial tunnel. Of the 2 leading sutures, 1 was removed and the other remained slung over the Ligament Washer. Each string of the sling suture was

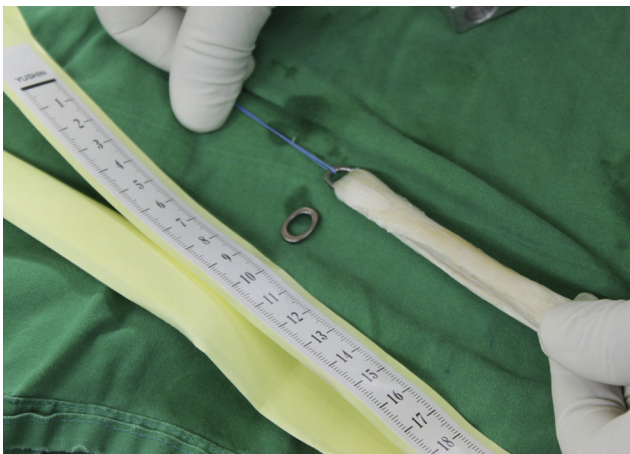


Fig 1. The graft is folded into 2 strands and is trimmed to fit the 10-mm tunnel. The graft is looped over the oval-shaped Ligament Washer. The length of the graft is set at 11 to 11.5 cm.

inserted into each hole of a 17-mm Suture Washer (Smith & Nephew) (Fig 2). Both ends of the sling suture and 1 end of the No. 2 FiberWire were tied together. Then, a closed loop of No. 2 Ethibond, which was tethered with No. 2 FiberWire, became looped over both the Ligament Washer in the tibial tunnel and the 17-mm Suture Washer at the anterior aperture of the tibial tunnel. While the opposite end of the tethering suture of No. 2 FiberWire was held using a hemostat to prevent it from becoming entangled in the tibial tunnel, the closed loop of No. 2 Ethibond was revolved 5 times around the Ligament Washer and 17-mm Suture Washer to make a 5-time winding looping suture of No. 2 FiberWire. Then, the tie was cut and No. 2 Ethibond removed. Pre-tensioning of the graft with slight manual tension at each end of the remaining No. 2 FiberWire was performed by cyclic range of knee motion with an anterior drawing force at the proximal tibia. The force pulling both ends of the multiple looping suture does not need to be strong because the overall pulling power of the 5-time winding looping suture might be enough with a small amount of tension of both ends of the multiple looping suture. After pre-tensioning of the graft, both ends were tied to each other with knee flexion of 90° (Fig 3). Tips for each step of our surgical technique are summarized in Table 1.

Postoperative Rehabilitation

Quadriceps strengthening exercise was performed immediately after surgery. Partial weight bearing was allowed on the second postoperative day, with full weight bearing as tolerated. A brace was applied for 2 months; it was fixed in extension for 5 weeks and allowed motion from 0° to 135° afterward. Continuous passive motion exercise was performed starting at 50° after 5 weeks postoperatively and progressing up to 120° at 2 months postoperatively. Hamstring exercise, stationary bicycling, proprioception exercise, and jogging were allowed at 3 months after surgery. Competitive sports except for those that might involve strong contact with other players, such as football or soccer, or those that might impose strong external forces on the patient's knee, such as skiing or snowboarding, were allowed at 9 months after surgery. All kinds of exercises were allowed after 1 year.

Discussion

The outcomes of PCL reconstruction are not as predictable as those of ACL reconstruction, the reasons for which are supposed to be tunnel placement,¹⁵⁻¹⁷ graft selection,¹⁸ tensioning condition,¹⁹ and fixation method. However, it is unclear whether the inconsistent outcomes of PCL reconstruction are caused by current techniques or not. The technique for fixation of the graft to the tibia has recently been of specific interest. The rehabilitation program including

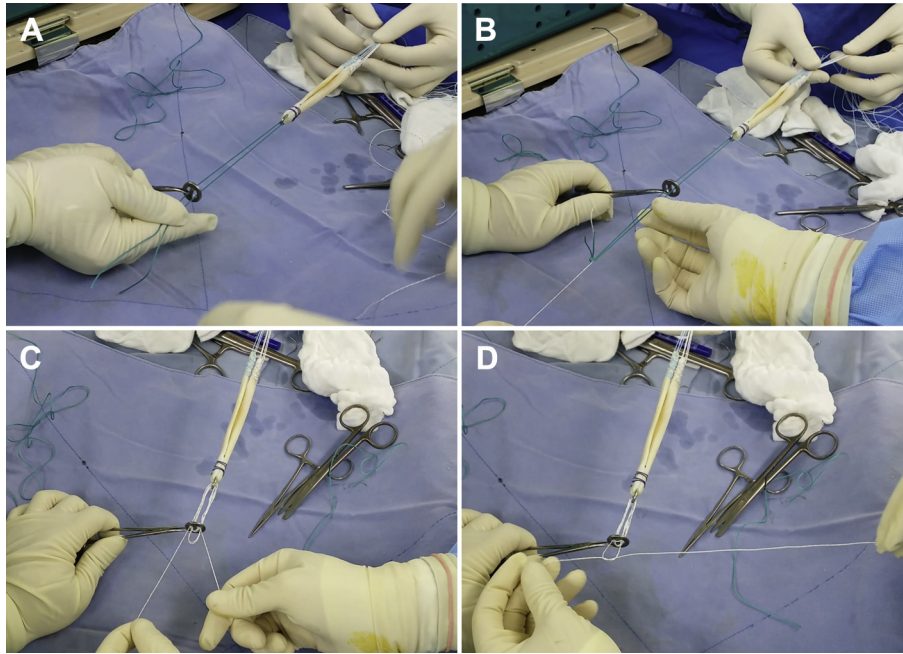


Fig 2. Creation of multiple loops using the Ligament Washer, which is supposed to be in the tibial tunnel, versus the 17-mm Suture Washer, which is supposed to be at the anterior aperture of the tibial tunnel, after insertion of the tibial end of the graft into the tunnel. (A) Each string of the No. 2 Ethibond sling suture (green) is inserted into each hole of the 17-mm Suture Washer. (B) Both ends of the sling suture of No. 2 Ethibond and 1 end of No. 2 FiberWire (white) are tied together. Then, a closed loop of No. 2 Ethibond, which is tethered with No. 2 FiberWire, becomes looped over both the Ligament Washer and the 17-mm Suture Washer. (C) After the closed loop of No. 2 Ethibond is revolved 5 times around the Ligament Washer and 17-mm Suture Washer in one direction and the No. 2 Ethibond is removed, 5-time winding loops of No. 2 FiberWire are created. (D) After both ends of the suture are pulled gently to make the tension of each loop evenly distributed, they are tied together.

delayed mobilization and weight bearing after PCL reconstruction using this technique was not as accelerated as the rehabilitation programs after ACL reconstruction. After PCL reconstruction, the supine position of the patient may adversely affect the tautness of the graft due to the posterior translation effect of gravity. Therefore the fixation strength should be strong and stiff enough to withstand the stress to the graft.

Our fixation technique has never been introduced before, although it may appear similar to conventional sling techniques such as EndoButton (Smith & Nephew) or EndoPearl (Linvatec, Largo, FL) techniques. We applied a pulley principle to the tibial fixation. This fixation technique has some advantages (Table 2). First, the failure load of the string material of the sling does not have to be larger than the stress on the PCL graft. Theoretically, when the string winds twice, the failure load is quadruple that of the string. When the string winds 5 times, the failure load becomes 10 times that of the string. Second, fewer problems occur when fixation is performed after fixation of the opposite end. When the opposite end is fixed first, there may be concern about the laxity of up to a few millimeters due to knot slippage if another sling or post-tie fixation technique is used at the tibial end. By use of

this technique, knot slippage during tying is distributed across the entire length of the winding string. If knot slippage of 1 mm occurs, the slippage is distributed across the entire length of the 5-time winding string resulting the laxity of 0.1 mm. Our technique is different from that in which 5 independent sutures

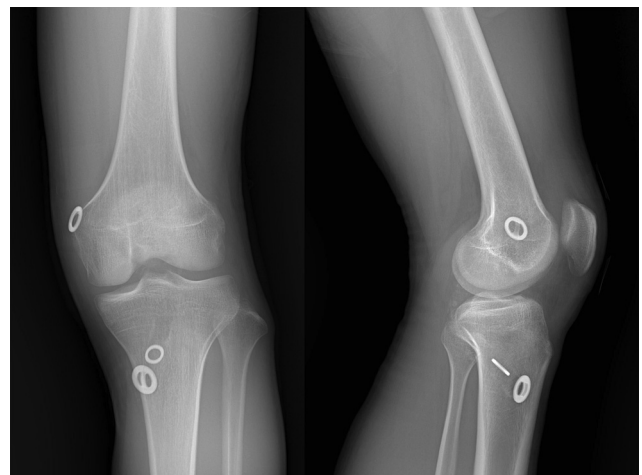


Fig 3. Postoperative anteroposterior and lateral radiographs of knee.

Table 1. Technical Steps and Tips and Pearls for Multiple Looping Technique for Tibial Fixation in PCL Reconstruction

Steps	Tips and Pearls
Establishment of anterolateral portal	Make an incision in the skin long enough (>1.5 cm) to pass the graft with double thickness of the original graft.
Graft passage into femoral tunnel	Be sure that the leading suture of the femoral tunnel is not entangled with that of the tibial tunnel.
Fixation at femoral tunnel	It is better to knot several times and ram the suture knot into the femoral tunnel through the hole of the Suture Washer to avoid irritation of the soft tissue postoperatively.
Graft passage into tibial tunnel	Pre-tension the graft that is fixed in the femoral tunnel beforehand. To ease the passage of the Ligament Washer-graft composite through the anterolateral portal and intra-articular aperture into the tibial tunnel, flex and extend the knee repeatedly during passage. To be sure that the tibial end of the graft is placed in the tibial tunnel correctly, use arthroscopy through the anterior aperture of the tibial tunnel.
Fixation at tibial tunnel	To avoid too much tension on the graft, do not make the knots too tight. To avoid too much tension on the graft, it is better to knot the multiple looping suture over a 1-mm-thick flexible guidewire, which is used for interference screw fixation, and the 17-mm Suture Washer and to remove the guidewire after knotting. If the whole femoral tunnel is reamed with a 10-mm reamer, care should be taken to avoid penetration of the 15-mm Suture Washer into the medial femoral condyle, breaking the cortical rim of the aperture, which is not uncommon when the 15-mm Suture Washer is placed eccentrically. It is better to knot several times and ram the suture knot into the tibial tunnel through the hole of the Suture Washer to avoid irritation of the soft tissue postoperatively.

sling the graft and each sling is independently tied, which may have issues regarding uneven tension on each sling and the possibility of laxity during tying or rupture of the string during follow-up. However, there may be concern that the Ligament Washer that slings the graft remains in the bone, which may make the removal of the implant difficult.

The described technique was based on single-bundle PCL reconstruction. Whether the outcomes of double-bundle PCL reconstruction are superior to those of single-bundle PCL reconstruction has been debated. In a review of the results of single-bundle transtibial PCL reconstruction, Kim et al.²⁰ stated that a significant number of patients showed residual laxity. Whiddon

Table 2. Advantages and Disadvantages of Multiple Looping Technique for PCL Reconstruction

Advantages	The failure load of the fixative composite is theoretically several times as strong as that of looping suture material. The adverse effect of knot loosening—if it ever occurs—is minimal on the laxity of the graft-fixative construct. Changing the looping suture into a new one is not difficult if the looping suture is ever damaged.
Disadvantages	It is not easy to adjust the tension of the graft when tightening the loops. It is better for the surgeon to tighten the loops a little bit less than he or she thinks is necessary. It may be difficult to remove the Ligament Washer once the tibial tunnel is filled with new bone. However, the Ligament Washer will rarely cause any problems if retained.

et al.²¹ reported that the benefits of double-bundle PCL reconstruction may not be realized in the context of an isolated PCL injury. Kim et al.²² stated that double-bundle PCL reconstruction combined with posterolateral corner reconstruction did not appear to have advantages over single-bundle PCL reconstruction combined with posterolateral corner reconstruction with respect to clinical outcomes or posterior knee stability. In addition, Markolf et al.²³ indicated that the need for a posteromedial graft during PCL reconstruction is in question.

At the beginning of the application of the described technique, we did not use a Ligament Washer to sling the loop of the graft; rather, the graft was looped over the suture directly. There was concern that the graft would be partially or completely cut by the suture during tensioning and tightening with the initial technique, although complete rupture did not actually occur. In addition, there was difficulty in changing the sling suture because of friction between the sling suture and the graft.

The cruciate ligaments are loaded up to 450 N during activities of daily living.^{24,25} Lee et al.²⁶ reported in their cadaveric study that the failure load of tibial fixation was 570 N with the TransFix device (Arthrex) and 370 N with an interference screw. A titanium ring has a yield strength of more than 950 to 1,000 MPa. Therefore a titanium ring with a 1.5-mm-thick rim is supposed to have sufficient failure load compared with the TransFix device or interference screw theoretically. Although a biomechanical study was not performed, the failure load was about 1,500 N in a pilot study; the mechanism of failure was suture breakage in all cases, and metal failure did not occur. Further studies may be needed to validate the biomechanical properties of this new fixation technique.

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