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Novel techniques

Arthroscopic-assisted anatomical reconstruction of the posterolateral corner of the knee joint

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ABSTRACT

Several surgical techniques have been suggested to anatomically reconstruct the posterolateral corner of the knee joint. However, most of them are open techniques that require dissection of the skin and soft tissues without utilizing the advantages of arthroscopic-assisted techniques. Therefore, this study aimed to describe a novel arthroscopic technique that anatomically reconstructs the posterolateral corner of the knee joint. This novel arthroscopic technique can properly identify important landmarks for reconstruction and anatomically reconstruct the three key components (lateral collateral ligament, popliteus tendon, and popliteofibular ligament) of the posterolateral corner of the knee joint.

1. Introduction

The posterolateral corner (PLC) of the knee joint is a complex area composed of multiple ligamentous and musculotendinous structures that provide stability against varus, external rotation, and posterior translation of the tibia [1]. Due to the limited understanding of its structures and biomechanics, it had been referred to as 'the dark side of the knee joint' [2]. However, over the past two decades, various studies have led to an advanced understanding of the complex PLC anatomy and biomechanically validated reconstruction techniques of PLC injuries [1,3–6].

Orthopedic surgeons have difficulty in diagnosing and treating PLC injuries, which are commonly related to posterior cruciate ligament (PCL) or anterior cruciate ligament (ACL) injuries; approximately 28% of all PLC injuries occur in the isolated form [7]. Although the primary repair of PLC injuries has been reported to show good outcome in the acute period within three weeks, it cannot be performed in chronic cases [8]. Therefore, reconstruction, tenodesis, osteotomy, and advancement procedures have been suggested for chronic PLC injuries [8]. Nowadays, anatomical PLC reconstruction technique is emphasized by restoring the

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three key structural components – the lateral collateral ligament (LCL), popliteal tendon (PT), and popliteofibular ligament (PFL) – in order to restore optimal stability and function.

Since LaPrade et al. first reported an anatomical PLC reconstruction technique in the literature in 2004 [4], various studies have been conducted regarding anatomical reconstruction with improved clinical outcomes [8]. However, most of them are open techniques that require a large lateral incision and extensive soft tissue dissection, without using the advantages of arthroscopic-assisted techniques [9–10]. Recently, some reports have described the arthroscopic anatomical reconstruction for posterolateral structures [9–12]. However, these reconstruction techniques were only performed on a single structure such as the popliteal tendon or popliteofibular ligament. Therefore, a novel arthroscopic-assisted procedure for anatomical PLC reconstruction was developed, which is presented in this paper.

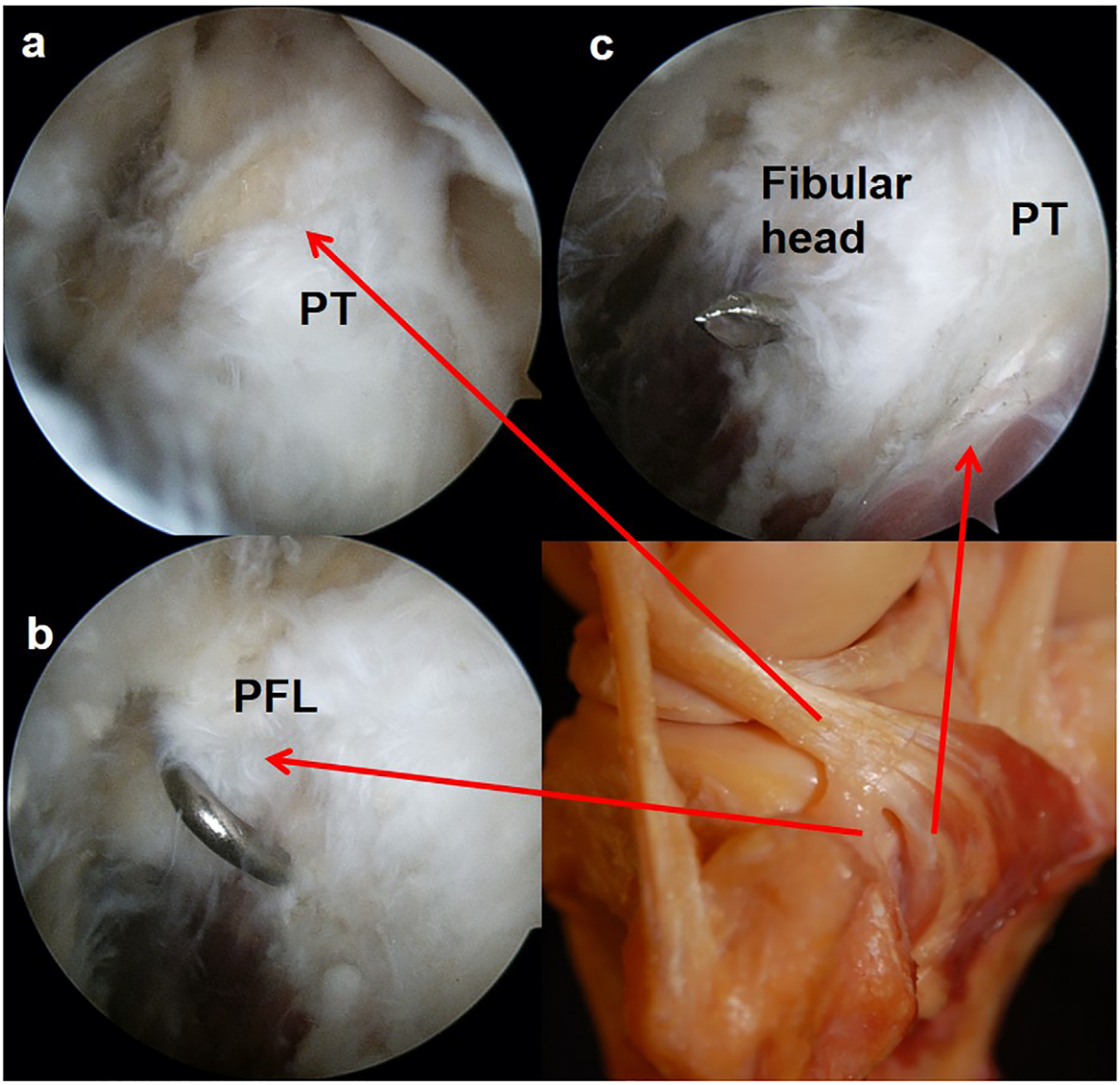

Figure 1. The arthroscope is introduced via the posteromedial portal and passed through the posterior trans-septal portal. Then, the arthroscope reaches the posterolateral compartment. After the posterolateral joint capsule is carefully separated from the synovial edge of the lateral meniscus posterior horn, the popliteal tendon (PT), fibular head, and popliteofibular ligament (PFL) are identified. a) The PT is visible. b) The PFL is checked using a probe. c) The musculotendinous junction of the PT is visualized. The tip of a guide pin for fibular tunnel is identified.

2. Surgical technique

2.1. Diagnostic examination through anterior portals and graft preparation

Under general or spinal anesthesia, the patient is placed in the supine position with the affected knee flexed to 80–90°. Standard anterolateral (AL) and anteromedial (AM) portals are established, and a routine diagnostic examination is performed using a four-millimeter 30° arthroscope. During the diagnostic examination, the PT is visualized through the lateral compartment and lateral gutter. In cases of chronic PLC injuries, the 'lateral gutter drive-through' test is positive with the knee at 30° flexion [13]. After the diagnostic examination, a tendon graft is harvested and prepared using an autologous hamstring (semitendinosus) tendon by the standard method or using an allogeneic tibialis anterior tendon. Usually, a five-millimeter diameter graft is used. A No. 2 Ethibond suture is used in a whip-stitch fashion on each end of the graft.

2.2. Diagnostic examination through posterior portals and identification of the PT and PFL

Posteromedial (PM), posterolateral (PL), and posterior trans-septal (PTS) portals are sequentially established under direct arthroscopic visualization, as previously described by Ahn et al. [14] The arthroscope is introduced via the PM portal and passed through the PTS portal to the posterolateral compartment. The PT can be visualized, and probing is performed through the PL portal. The posterolateral joint capsule is carefully separated from the synovial edge of the lateral meniscus posterior horn using an electric shaver and curette. Then, the posterolateral head of tibia and musculotendinous junction of the PT can be visualized. Further downward release of the posterolateral capsule of >10 mm from the tibial articular surface is performed to identify the musculotendinous junction of the PT, and then the proximal tibio-fibular junction and PFL can be visualized (Figure 1).

2.3. Establishment of inferior posterolateral portal and loop wire application for the PFL reconstruction

An accessory portal – the 'inferior PL portal' – is established just above the posterosuperior aspect of the fibular head. A spinal needle is percutaneously inserted at a site approximately five millimeters above the footprint area of the PFL on the fibular head through an outside-in technique (Figure 2a). A small stab wound is made using a No. 11 blade at the puncture site and enlarged with a straight hemostat. Then, a stab incision is made at the site of the PFL proximal original attachment site on the PT through the inferior PL portal to anatomically reconstruct the PT and PFL using a sling technique. The surgeon enlarges the stab incision using a straight hemostat. A loop wire is then inserted into the incision, with a grasper via the inferior PL portal, and passed through the incision at the proximal PFL anatomical attachment site on the PT. The loop end is pulled out through the PL portal using a retriever (Figure 2b).

2.4. Fibular tunnel formation

The fibular footprint of the PFL is marked using an electrocautery device. The surgeon places an ACL tibial guide on the fibular footprint of the PFL on the posteromedial down slope of the fibular styloid through the inferior PL portal. After making a minimal skin incision on the anterolateral aspect of the fibular head, a guide pin is inserted from the distal footprint of the LCL on the anterolateral aspect of the fibular head (Figure 2c). Along the guide pin, a bony tunnel is made using a seven-millimeter or eight-millimeter cannulated reamer, depending on the diameter of the graft. Then, the other side end of the loop wire is pulled out through the fibular head tunnel, using a grasper, from the posteromedial to anterolateral side. Later, this loop wire will be used as a shuttle for anatomic reconstruction of the PT and PFL.

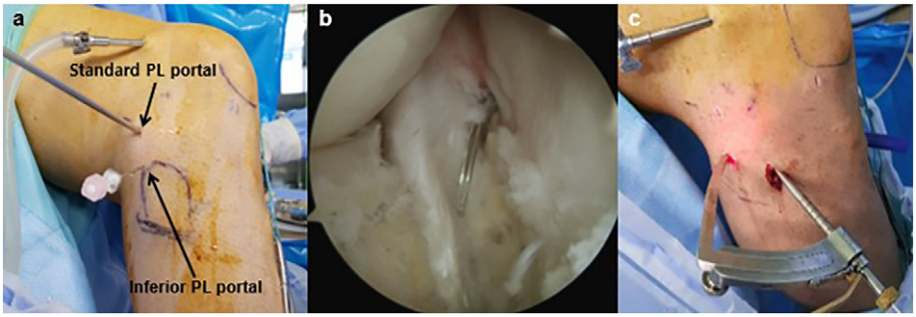

Figure 2. a) The inferior posterolateral (PL) portal is established just above the posterosuperior aspect of the fibular head. A spinal needle is percutaneously inserted at a site approximately 5 mm above the footprint area of the popliteofibular ligament (PFL) on the fibular head through an outside-in technique. b) A loop wire passes the musculotendinous junction of the popliteal tendon (PT) to anatomically reconstruct the popliteofibular ligament (PFL). c) An ACL tibial guide is placed on the fibular footprint of the PFL on the posteromedial down slope of the fibular styloid through inferior PL portal. After making a minimal skin incision on the anterolateral aspect of the fibular head, a guide pin is inserted from the distal footprint of the LCL on the anterolateral aspect of the fibular head.

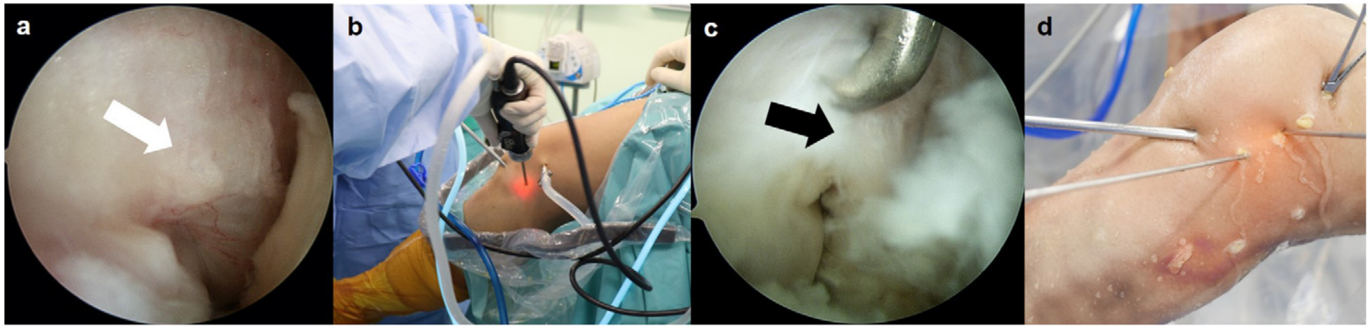

Figure 3. a) The synovium covering the femoral attachment of the PT is easily visible. b) The synovium covering the femoral attachment of the LCL and PT is debrided using an electric shaver through an accessory superolateral portal. c) After debridement of the synovium, the femoral footprint of the PT is identified by probing. d) Guide pins are inserted percutaneously on the femoral footprint of the popliteal tendon (PT) and lateral collateral ligament under arthroscopic guidance.

2.5. Femoral tunnel formation for the reconstruction of the LCL and PT

At 20–30° of knee flexion, the arthroscope is introduced into the knee joint through the AL portal and advanced into the lateral gutter. The synovium covering the LCL and PT is also easily identified (Figure 3a). The surgeon inserts an electric shaver through an accessory superolateral portal, which is established close to the femoral insertion area of the PT and LCL (Figure 3b). The synovium covering the femoral attachment of the LCL and PT is debrided using an electric shaver. The femoral footprints of the LCL and PT are then visualized (Figure 3c). A guide pin is placed percutaneously on the femoral footprint of the PT in a slightly upward (proximal) direction. Another guide pin is placed percutaneously on the femoral footprint of the LCL in a slightly downward (distal) direction (Figure 3d). After making a small skin incision at the pin sites, along the guide pins, bony tunnels are made using a five-millimeter diameter cannulated reamer to bridge under the cortex. Later, a tendon graft is passed under the cortical bony bridge (Figure 4). Using an instrument such as a towel clip, the communication between the two bony tunnels is enlarged for later tendon graft passage.

2.6. Graft passage and fixation

A suture loop is inserted into the PT femoral tunnel and advanced to pass through the LCL femoral tunnel. One end of the prepared tendon graft (single-stranded autologous semitendinosus or allogeneic tibialis tendon) is delivered into the LCL femoral tunnel using the shuttle loop, passed under the cortex bone bridge, and pulled out through the PT femoral tunnel. Then, the graft is divided into three portions: PT portion, graft under the femoral cortex, and LCL portion. A retriever is inserted through a small skin incision just anterior to the fibular footprint of the LCL and advanced deep to the iliotibial band reaching the femoral footprint of the LCL. A passing suture at the end of the LCL portion is pulled out using the retriever and then retrieved through the fibular head tunnel from the anterolateral to posteromedial side using another retriever that is inserted through the inferior PL portal. A retriever is then inserted through the PL portal and advanced deep to the LCL portion of the graft, reaching the femoral footprint of the PT. A passing suture at the end of the PT portion of the graft is retrieved through the PL portal using a retriever. The passing suture is introduced into the previously applied loop wire that passes the musculotendinous junction of the PT and then the fibular head tunnel. The distal portion of the loop wire is pulled, and the passing suture at the end of PT portion is brought out through the fibular tunnel from the posteromedial to anterolateral side. Lastly, both ends of the graft are simultaneously tightened in the fibular head tunnel by pulling the passing sutures at both ends of the graft. After the graft is tensioned by repetitive passive range of motion, the surgeon fixes the graft by fibular tunnel fixation using a seven-millimeter or eight-millimeter bioabsorbable interference screw while the knee joint is located at neutral tibial rotation and 30° flexion (Figure 5).

3. Discussion

The most important finding of the present study is that the three key components (LCL, PT, and PFL) of the PLC structure could be anatomically reconstructed using an all-arthroscopic technique. Each landmark for anatomical reconstruction could be properly identified arthroscopically, which is not possible with the open technique.

Nowadays, anatomical reconstruction of the PLC is commonly performed in chronic PLC injuries. However, the guidelines for PLC reconstruction remain unclear, and several surgical techniques for PLC reconstruction have been suggested, such as open techniques with a large lateral incision and extensive soft tissue dissection, without utilizing the advantages of arthroscopic-

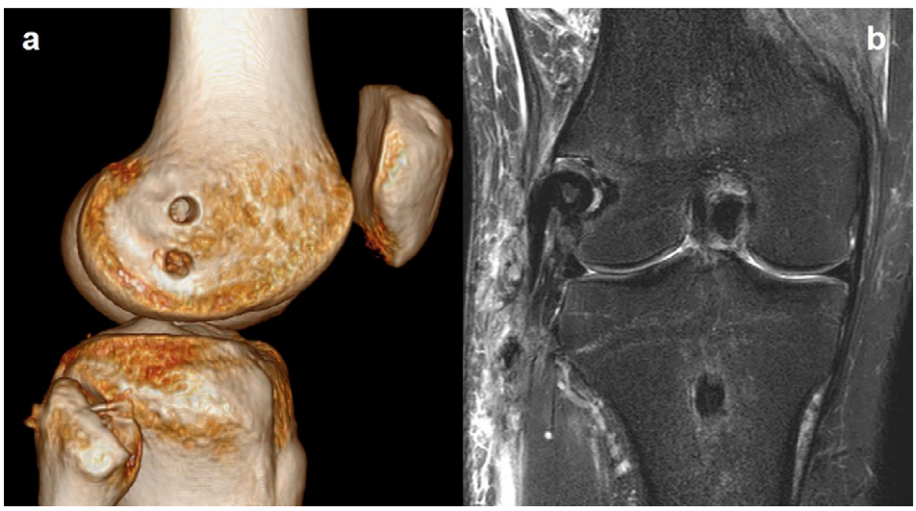

Figure 4. a) Postoperative CT scan shows anatomical placement of the femoral tunnels. b) Postoperative MRI shows that a tendon graft is passed under the femoral cortical bony bridge.

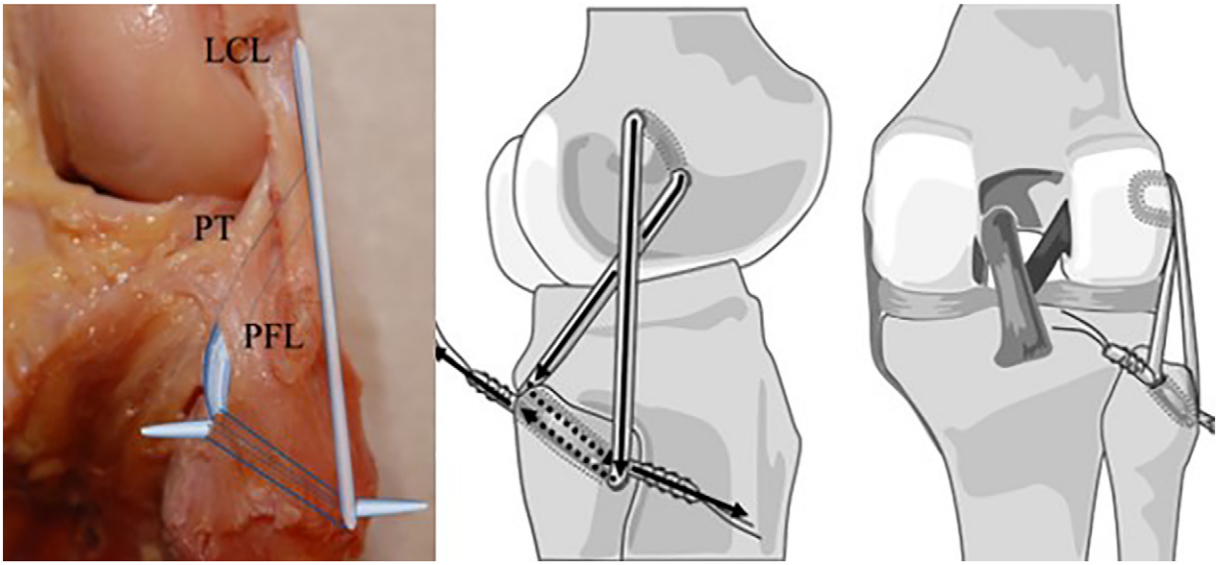

Figure 5. Schematic illustrations for overall graft passage and fixation. One end of the prepared tendon graft is delivered into the LCL femoral tunnel, passed under the cortex bone bridge, and pulled out through the PT femoral tunnel. The end of LCL portion of the graft is pulled out and retrieved through the fibular head tunnel from the anterolateral to posteromedial side. Then, the end of PT portion of the graft is retrieved deep to the LCL. It passes the musculotendinous junction of the PT and is then brought out through the fibular tunnel from the posteromedial to anterolateral side. Lastly, both ends of the graft are simultaneously tightened in the fibular head tunnel and fixed using a bioabsorbable interference screw.

assisted techniques [6,15–19]. Furthermore, the distal insertion of the PFL is located deeply on the posteromedial aspect of the fibular head. In open technique surgeries, this footprint is very difficult to identify and usually detected with an indirect method such as finger touch [10]. Recently, some authors developed arthroscopic-assisted reconstruction techniques [9–11]. However, these techniques reconstruct a single structure only, such as PT or PFL. Therefore, a novel all-arthroscopic technique was developed, with the following advantages [1]: an all-arthroscopic anatomical reconstruction technique for chronic PLC injuries [2]; visualization of all anatomical landmarks for PLC reconstruction including femoral insertion of PT and LCL, and proximal and distal insertion of PFL under direct arthroscopic guide [3]; all three important components of the PLC structure (PT, LCL, and PFL) can be reconstructed [4]; infection rates, postoperative soft tissue contracture, and postoperative pain can be reduced by using small incisions [5]; visualization and protection of the peroneal nerve are unnecessary.

LaPrade et al. firstly reported a surgical technique to treat posterolateral knee instability that anatomically reconstructs three major structures of the PLC: the LCL, PT, and PFL [4]. Thereafter, many orthopedic surgeons have performed anatomical PLC reconstruction using the technique by making a tibial tunnel to reconstruct the PT and PFL. Although LaPrade et al. demonstrated that their technique is anatomical reconstruction of the PLC structure, to be exact, the PFL could not be reconstructed anatomically in their technique because the proximal PFL is fixed on the posterior popliteal sulcus of the lateral tibial condyle. The PFL is found at the musculotendinous junction of the PT and distally inserts into the posteromedial aspect of the fibular head [1]. Therefore, for proper anatomical reconstruction the proximal PT should be attached to the original proximal site at the musculotendinous junction of the PT. In the current novel arthroscopic technique, the tendon graft was proximally fixed on the anatomical femoral footprint of the PT, coursed downward along with native PT, pierced in the native PT at the level of musculotendinous junction, and finally fixed distally on the posteromedial aspect of the fibular head. Therefore, this technique could anatomically reconstruct the PT and PLT by making a sling on the musculotendinous junction of the native PT. The proximal and distal insertions of the PFL are difficult to identify with open or minimally invasive techniques. However, the PFL could be properly identified and anatomically reconstructed using the arthroscopic technique.

Although this novel technique has several advantages, some potential complications were still observed. First, the main structures and landmarks of the PLC would not be easily identified after injury. Therefore, exact understanding of the anatomy of the main structures and their footprints is mandatory before operation. There was a definite learning curve, as for other new surgical skills. To reduce surgical errors and achieve proper orientation, this novel technique was practiced several times on cadaveric knee joints with an uninjured posterolateral corner. Furthermore, due to the complexity of the procedure, the operation time may be long. Accordingly, excessive soft tissue swelling, effusion, or compartment syndrome (rarely) can occur. Thus, to reduce these complications and overcome the learning curve, this procedure requires advanced arthroscopic skills and experience.

Second, the femoral origin of the LCL is more obscure than that of the PT, especially in cases of chronic PLC injuries. In cases where the remnant of the LCL is not visible, the use of intraoperative fluoroscopy may help to identify the femoral origin of the LCL [20]. A recent study demonstrated that a radiographic technique showed increased accuracy compared with the finger palpation technique for identifying the LCL femoral origin point [21]. Third, there is a risk for injury on the lateral inferior genicular artery, which is located closely posterior to the musculotendinous junction of the PT. Therefore, proper visualization and careful handling are necessary around the PT. Fourth, during the procedure, dissociation of the popliteomeniscal fascicles is needed, which can result in increased lateral meniscal instability [22–23].

Lastly, this novel technique is performed through several arthroscopic portals and small skin incisions. As LaPrade and Engebretsen warned in their editorial commentary, small incisions could limit the procedure and make big mistakes [24]. Furthermore, below the iliotibial tract, the posterior aspect of the LCL is directly connected to the lateral aponeurotic expansion of the biceps short head and covered laterally by the lateral aponeurosis of the biceps long head [25]. These complex soft tissue structures could make passage of the graft difficult. Therefore, surgeons should have exact knowledge of anatomy and the required experience. If necessary, to correctly perform a PLC reconstruction, additional small incisions or intraoperative fluoroscopic technique should be added when surgeons are unsure about the anatomy or feel difficulty during graft passage.

Declaration of Competing Interest

There are no conflicts of interest between any of the contributors to this manuscript.

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Ethics Committee Letter

This study is a technical note. This article does not violate any ethical principles or patients. No animal or human subjects were harmed for this study.

All authors (Jin Hwan Ahn, Joon Ho Wang, Seung-Yup Lee, Im Joo Rhyu, Dong Won Suh, and Ki-Mo Jang) took part in writing the manuscript and all agreed to accept equal responsibility for the accuracy of the content of the paper.

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