RESEARCH ARTICLE

Arthroscopic-Assisted Posterolateral Corner Reconstruction of the Knee: Novel Technique, Classification, Surgical Algorithm, and Midterm Results

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Received: 12 March 2024 *Accepted: 26 August 2024*

Abstract

Objectives: This study aimed to introduce a new arthroscopic method for reconstructing the popliteus tendon (PT). This minimally invasive technique is performed through the posterolateral corner (PLC) of the knee, which can reconstruct the posterolateral rotary instability (PLRI) of the knee.

Methods: Thirty-nine patients (8 females, 31 males) with PLC injury and normal knee alignment underwent arthroscopic PT reconstruction. Among them, 27 patients had combined ACL and PLC injuries, and 9 had been involved in PCL and PLRI. In 3 of them, injuries involved ACL, PCL, and PLC. Physical examination, imaging, and arthroscopic evaluation were performed to assess instability stages. In grade I instability, when the PT had not been injured, the patient was treated with the modified Larson technique and semitendinosus autograft. With grade II injury involving the PT component, arthroscopic reconstruction of the PT was the preferred technique. In grade III injuries, arthroscopic PT reconstruction and the modified Larson technique were used concurrently.

Results: All patients were followed up for 58 ± 1 months postoperatively. Varus and external rotation instability were restored with arthroscopic PLC reconstruction. All patients gained near-normal knee stability and significant improvement with pain, along with improved ability to carry out daily activities. In cases of varus instability, a considerable improvement was observed in external rotation and reverse pivot shift. There were no cases of arthrofibrosis or limitations in knee motion.

Conclusion: Arthroscopic reconstruction of the PT, using our protocol for PLC reconstruction of the knee (with midterm follow-up), showed encouraging results while minimizing surgical morbidity.

Level of evidence: IV

Keywords: Arthroscopy, Knee instability, Popliteus tendon, Posterolateral corner reconstruction

Introduction

The posterolateral corner (PLC) plays a vital role in stabilizing the knee. Its main components are the lateral collateral ligament (LCL), popliteus tendon (PT), and popliteofibular ligament (PFL).[1] The role of the PLC is well-established in the opposing varus, posterior-directed, and external rotation forces.[2] Injuries to the PLC often present the most challenging problems and can result in rotary instability, accompanied by ligament and cartilage complications.[3] Moreover, the root attachment of the lateral meniscus is looser than the medial meniscus, and an injury to the PLC can result in meniscus instability.[4-6] Neglecting the PLC can cause graft failure in isolated ACL/PCL reconstruction. However, no reconstruction technique has provided optimal stability after PLC injuries.

Grading systems for the clinical examination have been used to ensure the efficacy of the related procedures.[7,8] Hughston grade I injury has a < 5mm joint line opening in the stress test. Grade II is defined as an opening of 6-10mm, while grade III is marked by an opening greater than 10mm. The arthroscopic gap test is characterized by joint separation between articular surfaces and an increase in the lateral tibiofemoral joint opening, measured at 25° knee

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flexion [Figure 1].[2] Furthermore, the "drive-through sign," a high level of lateral joint laxity, in arthroscopy is used to confirm PLC insufficiency.[9,10] LaPrade et al. found that there was no nonoperative method to treat grade III PLC injuries.[9,10] Kannus reported that grade II PLC injuries could be healed nonoperatively, however, they would leave a lateral laxity, while nonoperative management of grade III injuries would lead to devastating results.[11] Concurrent injuries to the cruciate ligaments should be addressed, and overall mechanical alignment of the knee should be taken into account. Varus deformity exerts an overstress on the PLC and undermines the repair or reconstruction; thus, before the reconstruction of chronic injuries, varus deformity should be corrected by high tibial osteotomy (HTO).[10]

Although it is difficult to determine which reconstruction method offers the best results, the LaPrade technique for PT reconstruction seems to be the most anatomic approach, showing excellent outcomes in PLC injuries.[12-14] Nevertheless, it is a major open surgical approach. This study aimed to introduce a minimally invasive modification of previous techniques and develop a more practical classification and surgical algorithm.

Figure 1. Posterolateral varus stress test, 10° flexion

Materials and Methods

Patients

From August 2005 to April 2010, patients with chronic PLC injury who received arthroscopic-assisted treatment were included in this study. Patients with grade I and IV PLC injury and acute PLC were excluded from the study. Patients with grade I, who were not treated with PT reconstruction, were excluded as well. Patients with grade IV patients were also excluded to minimize the impact of HTO on the outcomes. Overall, 39 patients (8 females and 31 males) were included and classified into either grade II or III with PLC injury and were treated with the arthroscopic-assisted method of PLC reconstruction.

Diagnosis

Physical diagnosis included the varus stress test while the knee was extended or slightly flexed, the reverse pivot shift test, and the external rotation recurvatum test.[1,7,15,16] The varus thrust gait was evaluated to detect chronic varus and external rotation instability of the knee. Functional standing stress X-rays were also obtained.[17] Further investigations, including magnetic resonance imaging (MRI), were conducted as necessary to identify complex PLC injuries, along with long-leg radiographs to assess the alignment of the lower limbs. Additional studies, such as MRI, were performed if needed to detect complex PLC injuries and long-leg radiographs to evaluate lower limb alignment [Figure 2].

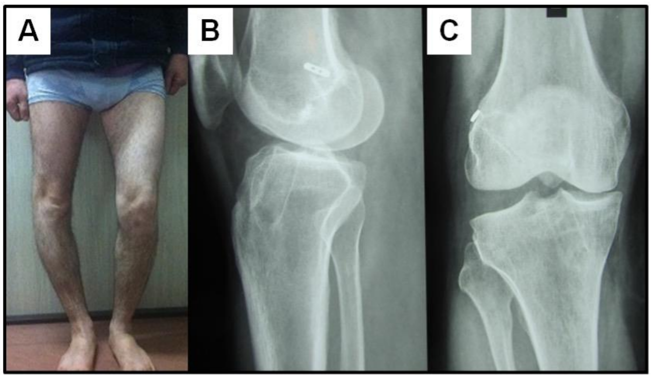


Figure 2. (A) Functional one-leg standing X-ray, (B) Lateral, and (C) Anterior-posterior views with patient weighting on the involved knee and relaxing the contralateral knee

Arthroscopic inclusion criteria for surgical reconstruction [Figure 3a] were the gap test measurement as stated earlier[18,19] [Figure 3b], abnormal "drive-through sign," in which there was > 10 mm of lateral opening and exceptional visualization of the inferior surface of the lateral meniscus [Figure 3c].

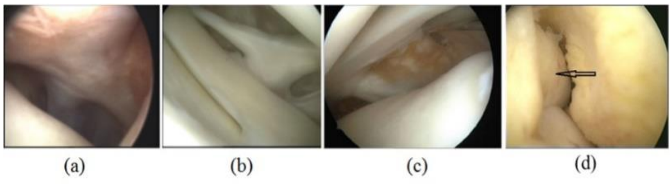


Figure 3. (a) Arthroscopic view of the arcuate complex, (b) Gap sign and severe PT injury, (c) Drive-through sign, (d) Femoral attachment site of an intact PT

Authors' Suggested Grading System

The following grading system has been suggested as being the most effective in both general management and the surgical approach. The highest grading in each parameter is considered the total grade of the knee.

Grade I: Normal or mild varus alignment; < 5 mm lateral joint line opening in posterolateral varus stress test with knee extension or few degrees of flexion [Figure 1]; < 5 mm lateral joint line opening in functional standing stress X-ray [Figure 2]; no varus thrust gait; and intact PT in the arthroscopy.

Grade II: Normal or mild varus alignment; 6-10 mm lateral joint line opening in posterolateral varus stress test with knee extension or few degrees of flexion; 6-10 mm lateral joint line opening in functional standing stress X-ray; no varus thrust gait; arthroscopic gap test approximately 10 mm; and attenuated or lose PT.

Grade III: Normal or mild varus alignment; > 10 mm lateral joint line opening in posterolateral varus stress test with knee extension or few degrees of flexion; > 10 mm lateral joint line opening in functional standing stress X-ray; mild varus thrust gait; arthroscopic gap test approximately 10 mm; and attenuated or lose PT.

Grade IV: Varus alignment; > 10 mm lateral joint line opening in posterolateral varus stress with knee extension and 10° flexion; > 10 mm lateral joint line opening in functional standing stress X-ray; substantial varus thrust gait; arthroscopic gap test > 10 mm, and macroscopic tear of PT.

Surgical Algorithms

Corresponding surgical approaches based on these grading systems have been performed [Figure 4].

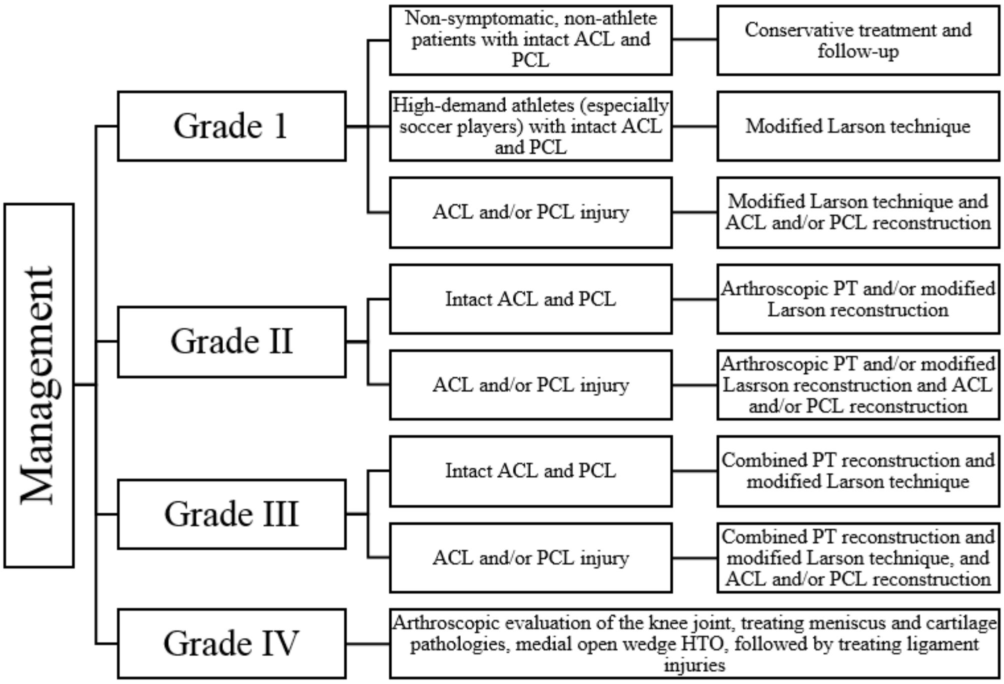


Figure 4. Algorithm for the management of PLC injuries

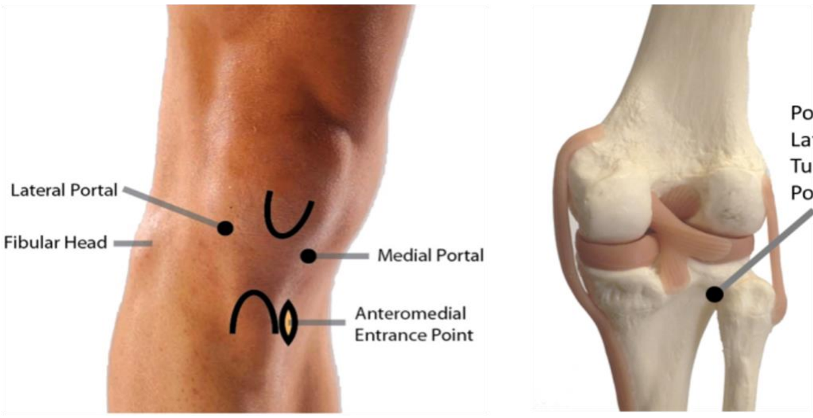
Surgical Technique

Graft Choice: Autogenous or allograft semitendinosus tendon was used for the modified Larson technique. For the PT reconstruction, tibialis posterior allograft was preferred; however, three to four-stranded semitendinosus tendons were used occasionally.

Creation of the tibial tunnel: The assessment of the joint and the treatment of meniscal and cartilage pathologies were conducted via the standard anterior arthroscopy portals [Video 1-4]. In case of a combined ACL and/or PCL injury, corresponding femoral tunnels were created. While the hip was at 45º abduction with external rotation, and the knee was at 45-70º flexion from the medial portal, the anatomical tunnel position of the tibial attachment of PT was prepared by a short PCL rasp below the lateral meniscus [Video 5, 6]. The direction of rasping was from medial to lateral, with the stop point being the resistance of the fibular head.

Through the lateral or medial portal, depending on knee size and degree of instability, a PCL jig or a hooked ACL jig was positioned 10-12 mm below the joint line and the lateral meniscus at the anatomic origin of the PT. We put the external arm of the jig medial to the tibial tubercle, and for concomitant bone-tendon-bone (BTB) reconstruction of the ACL, it was put in the crater of the BTB harvest. We created a tibial tunnel from the anterior part of the medial tibial plateau to the PLC, then medial to the tibiofibular joint [Figures 5 and 6].

Creation of the femoral tunnel: By probing through an accessory lateral gutter portal, the anatomic site of the PT insertion was determined. At this stage, gentle flexion and extension of the knee would help to find the precise attachment point of the PT. The guide pin was introduced through the lateral gutter in a proximal medial and anterior direction, while a 25- 30 mm tunnel was created in the lateral femoral condyle [Videos 7, 8].



(a) (b)

Figure 5. (a) Medial and lateral portal and anteromedial entrance point of the tibial tunnel, and (b) Posterolateral tunnel point

(a) (b)

Figure 6. Creation of the tibial tunnel: (a) right knee and (b) left knee

After establishing the tunnels, a loop-formed steel wire was passed through the anterior orifice of the tibial tunnel, retrieved from underneath the lateral meniscus, then passed through the popliteal hiatus of the lateral meniscus, parallel to the original PT, and thrown from the lateral gutter out of the skin [Video 9, 10]. We replaced the wire with #5 non-absorbable sutures and anchored the graft to the suture, which passed through the created tunnels [Figure 7]. We used a bio-interference screw for femoral side fixation, along with sufficient traction applied to the graft. Tibial side fixation was performed by a bio-interference screw and augmented by a tendon staple or non-absorbable sutures to the surrounding tissue. The final graft direction must be exactly tangential and parallel to remnants of the original PT [Videos 11-13]. In multiple ligament injuries, to prevent too much fluid loss and water turbulence, it is preferred to initially create femoral tunnels of ACL/PCL/PT and the tibial tunnels afterward.

Postoperative Rehabilitation

In our postoperative rehabilitation protocol, the knee was protected by a knee immobilizer and was used for eight weeks. Range of motion and isometric exercises were performed immediately after the first week. Weight-bearing activities were avoided in the first three weeks. Partial weight-bearing walking while wearing the brace was allowed after 3-6 weeks. Full weight-bearing activities with the immobilizer were allowed 6-8 weeks postoperatively. After 8 weeks, the knee immobilizer was removed. The post-operative protocol was adapted in case of combined lesions.

Outcome measures

Patients were prospectively followed at 3, 6, 12, and 24 months postoperatively, and after that, every two years. Age, gender, concurrent ligament, and meniscus injuries were recorded. The patients also completed the International Knee Documentation Committee (IKDC) 2000 and the Subjective Knee Evaluation Form preoperatively and in the last follow-up. The IKDC score was reported on a 0-100 scale, and the IKDC knee examination was reported on a four-grade scale with A (Normal), B (Nearly Normal), C (Abnormal), and D (Severely Abnormal).

Statistical Analysis

We used SPSS software (version 25) for data analysis. Categorical data were evaluated using mean ± standard deviation (SD), and quantitative data were reported using numbers and percentages. A p-value of < 0.05 was considered significant.

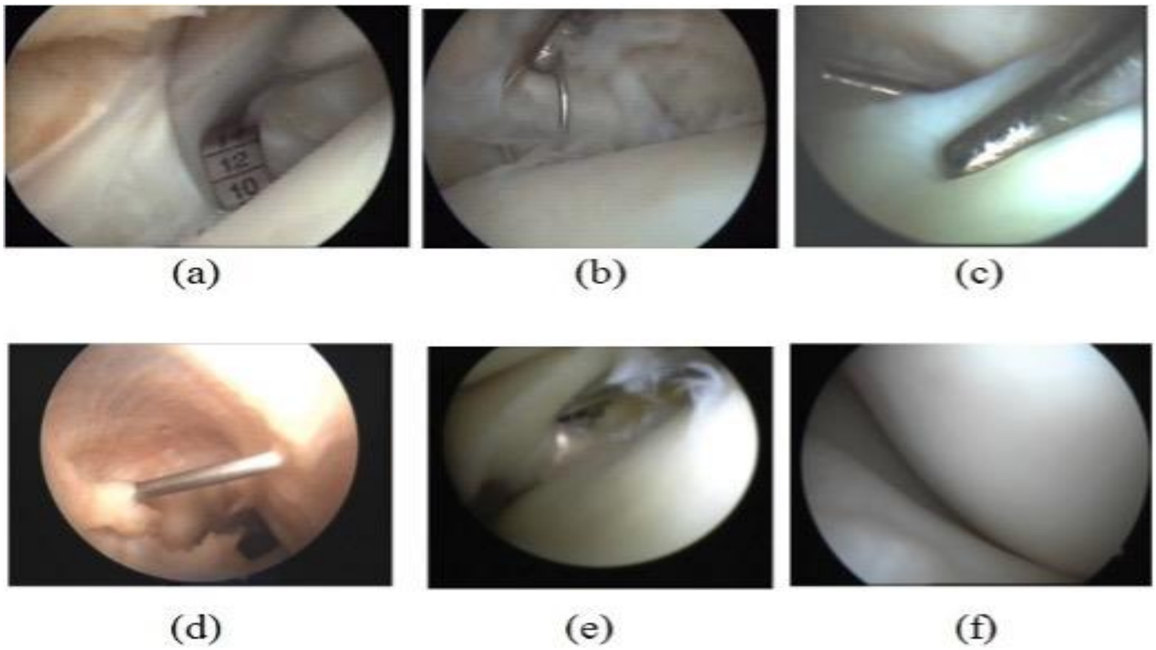


Figure 7. Illustration of the arthroscopic intra-articular steps: (a-c) Sequential steps of the jig position and passing of the looped steel wire from the tibial tunnel, popliteal hiatus of lateral meniscus and lateral gutter, (d) Guide pin in anatomic position of the PT in lateral femoral condyle, (e) End result in semi-figure of the knee before final fixation, and (f) Lateral joint line view after final fixation

Results

Thirty-nine patients (8 females, 31 males) with either grade II or III PLC injury underwent treatment with the arthroscopic-assisted posterolateral reconstruction method. All patients were followed up for a mean of 58 ± 1 (30-86) months postoperatively. The mean age of the patients was 27 (17-46) years, with all having chronic injuries for 3-32 months.

Among the patients, 27 (70%) had combined injuries of ACL and PLC, 9 (23%) had PLC and PCL damage, and 3 (7%) suffered from concurrent injuries of PLC, ACL, and PCL. In addition, 17 patients (43%) had accompanying meniscal injuries addressed by repair or meniscectomy. Medial meniscus injuries were observed more often than lateral meniscus injuries. In 5 cases (12%), there were chondral lesions that were debrided during the procedure.

The subjective IKDC score increased significantly (P<0.001) from 45.56 ± 5.65 preoperatively to 68.02 ± 8.04 at the last follow-up.

Varus and external rotation instability were restored with arthroscopic PLC reconstruction. All patients had nearly normal knee stability and significant grade improvement for the varus stress test, external rotation, and reverse pivot shift test. The clinical IKDC results are presented in [Table 1]. Other assessments have been done, according to the accompanying ACL or PCL reconstruction. There were no cases of arthrofibrosis. A full range of motion was achieved in nearly all patients.

Table 1. Pre-operative and last follow-up grades for the IKDC Knee Examination for External Rotation Test

IKDC Examination	Pre-operative	Last follow-up
A (Normal)	0 (0.0)	25 (64.1)
B (Nearly Normal)	0 (0.0)	14 (35.9)
C (Abnormal)	20 (51.3)	0 (0.0)
D (Severely Abnormal)	19 (48.7)	0 (0.0)

Data is presented as frequency (percent)

Discussion

Two main classification systems for PLC injuries include Hughston, and Fanelli and Larson.[7,8] The Hughston classification uses varus stress with the knee in full extension. Grades I to III show 0-15 mm of gap or 0-15° of rotation. In our classification, we defined a fourth grade that shows the same instability in the physical examination but has varus thrust.[7] The classification of Fanelli and Larson also describes the injury to different ligaments in PLC, in contrast to our suggested classification, which evaluates instability.[8]

Moreover, we did not include the dial test in our preoperative evaluations since although the dial test is shown to be help evaluate external rotation,[16] it is also affected by the injury of the medial collateral ligament and posteromedial corner and structural rotational malalignment of the lower limb and may influence the diagnosis of PLC injury, especially in inexperienced surgeons. We believe that clinical examination is a critical part of the diagnosis, along with X-ray, MRI, and long leg radiographs. It should be noted that the current expert consensus, in addition to clinical examination, suggests varus stress X-rays and MRIs, as well as chronic long-leg radiographs, for the diagnosis of PLC injury.[20]

It is recommended that the cruciate ligament be reconstructed in addition to the PLC reconstruction, as these injuries frequently happen in combination with cruciate ligament injuries.[21-23]

Reconstruction is recommended for higher-grade chronic PLC injuries.[3] various surgical techniques are described, each designed to restore stability and kinematics of the knee and return patients to pre-injury activities without pain and instability. We also believe that grades II, III, and IV require surgical intervention. The reconstruction techniques can be classified into anatomic and nonanatomic reconstructions, with the two main categories of anatomic reconstruction being fibular-based and tibiofibular-based procedures.[3] Although tibiofibular-based procedures are more anatomically accurate, fibular-based and tibiofibular-based procedures result in equally satisfactory clinical outcomes.[24,25] However, the tibiofibular-based procedures are longer and more invasive.[26]

Our preferred method of reconstruction for grade I injuries in a mild varus-aligned knee is a modified Larson technique.[27] In Larson's technique, the reconstruction aims to restore the function of the PFL and LCL. The author used semitendinosus autograft, while the posterior limb of this construct reproduced the function of the PFL, and the anterior limb reproduced the function of the LCL.[27] Our modified Larson PLC reconstruction method was performed with the semitendinosus tendon. Two separate 2.5-cm-long incisions were made over the fibular head and lateral epicondyle of the femur, although in most cases, the femoral tunnel was created by the arthroscopic technique. Our arthroscopic technique creates tibial and femoral tunnels more correctly and less invasively and follows the anatomic course of the PT more precisely parallel to its remnants, while there is no need for large exposure or exploration of the peroneal nerve. This arthroscopic-assisted method provides high knee stability with a low rate of complications and morbidity. We have employed this technique for several years and have achieved satisfactory results. The challenging aspect is the differentiation and treatment of grade II injuries, which heavily relies on the surgeon's experience. We highly recommend that junior surgeons who are uncertain about using the grade II or grade III technique approach the injury as a grade III and treat it accordingly.

LaPrade et al., based on anatomic and biomechanical studies,[9,10,13,14,28] introduced a PLC reconstruction technique that reconstructs the PT, the PFL, and the fibular collateral ligament with an allograft. Tunnel placement is designed on an anatomic basis to replicate normal anatomy as much as possible.[13] Even though the LaPrade technique seems to be the anatomic choice, it requires a large posterolateral knee approach, which complicates work on the fibular head and posterolateral tibial plateau, with the hazard of neurovascular damage. It is difficult to determine which method provides the best results. In open surgery, with a large posterolateral approach to the knee, the anatomical landmark (of the posterior orifice of the tibial tunnel of the PT graft) is not easily visible; with more dissection, there is potential to injure the intact remnants of the posterolateral stabilizing structures of the knee. An arthroscopic technique creates the tibial tunnel more correctly and follows the PT anatomic course more precisely (i.e., parallel to its remnants), eliminating the need for exposure or exploration of the peroneal nerve.

Miller et al. stated that the main structure in posterolateral rotary instability (PLRI) is the PT. They reported performing popliteal bypass with the use of the iliotibial band or the biceps tendon. In this method, the graft was passed through a transosseous tunnel from the area of the Gerdy tubercle to the PLC, replicating the course of the PT with emphasis on the repair of the deep layer, reattachment of the capsule and arcuate ligament to the posterior insertion of the lateral meniscus.[29] A similar technique was performed in the current study. Hughston described the posterolateral reconstruction by anterior and distal advancement of the insertion site of the lateral gastrocnemius tendon, fibular collateral ligament, and PT.[30] It relied on intact but loose structures; otherwise, this procedure would not have been able to restore joint stability.

Until 1996, biceps femoris tenodesis and rerouting at the lateral femoral condyle was Clancy's preference for the correction of a mild to moderate PLRI.[31] His current technique involves posterolateral reconstruction, utilizing half of the Achilles tendon allograft for this purpose and the other half for reconstructing the fibular collateral ligament.[31] Noyes et al. preferred an Achilles tendon-bone allograft when the popliteus muscle-tendon ligament was considered completely non-functional or with the bone portion of the graft placed at the anatomic femoral insertion site, and the collagenous portion of the graft passed into the tibial tunnel. A patellar tendon bone graft was used to replace LCL.[18,19] Another study used a similar technique for PLC reconstruction; however, it only described the results in six patients with promising results.[32]

In this study, a novel arthroscopic procedure for the reconstruction of the PLC is accompanied by less morbidity while preserving the native intact structures. The probability of a neurovascular injury was minimized, and there was no case of infection or arthrofibrosis in both short-term and long-term follow-ups. We have shown, in a relatively large number of patients (and long-term multi-phase follow-ups), that functional static and dynamic stability was achieved in almost all cases tracked by IKDC scores in multi-stage assessments. This study also had its limitations. We did not have a control group, which prevented us from conducting a cohort or case-control study. Additionally, we are reporting the results of a relatively outdated case series, and numerous studies have been published since then; however, we believe that the results of this case series can still be of interest.

Conclusion

Clinical results show a correction of rotational laxity compared to the preoperative condition. The results provided an improved function for daily activity and sports. In our opinion, the combination of PT reconstruction and the modified Larson technique showed the best results with Grade III instabilities. The procedure was technically demanding but was performed by surgeons who specialized in PCL reconstruction. The main advantage of this technique is the arthroscopic creation of the tibial tunnel. In small and tight knees, or the first few cases, the femoral tunnel should be created by a short incision over the lateral femoral condyle; otherwise, the femoral tunnel can be created arthroscopically.

Acknowledgement

The authors would like to thank the patients for their kind participation and cooperation in our study.

Authors Contribution:
Mohammad Razi conceptualized and supervised the study. Afsaneh Safar Cherati conceptualized the study and contributed to data collection. Haleh Dadgostar wrote the first draft of the study. Keyvan Ahadi contributed to data collection. Hajar Razi performed data analysis. Saeed Razi contributed to data collection. Mohammad Soleimani critically revised the manuscript. All authors approved the final version.

Declaration of Conflict of Interest: The author(s) do NOT have any potential conflicts of interest for this manuscript.

Declaration of Funding: The author(s) received NO financial support for the preparation, research, authorship, and publication of this manuscript.

Declaration of Ethical Approval for Study: N/A

Declaration of Informed Consent: All patients provided written informed consent before they participated in the study.

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