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Research Article

Revision Posterior Cruciate Ligament Reconstruction or Repair: A Systematic Review

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Abstract

Introduction: Recurrent posterior instability necessitating revision posterior cruciate ligament reconstruction is rare. The purpose of this study was to systematically evaluate all literature on revision PCLRs and analyze outcomes, complications, and reoperation rates in these patients.

Methods: Following the PRIMSA guidelines, a systematic review of the literature was performed. A comprehensive search of all literature published before August 2016 was performed and yielded a total of 1,479 studies. Articles containing data on revision PCL reconstruction cases were included, and 4 studies were utilized for this review after application of inclusion and exclusion criteria.

Results: Across all 4 studies, there were 43 cases that underwent revision PCLR and had sufficient follow-up. These patients had a mean age of 31.0 years, a mean length of 32.8 months between index surgery and revision reconstruction, and a mean follow-up of 41.0 months. Patient outcomes and knee stability improved significantly at time of the latest follow-up compared to the preoperative state. However, 15/37 (41%) cases had a complication, none of which were intraoperative. The majority of reported complications were significant motion loss and persistent knee laxity. A 13.3% revision failure rate was reported in one study.

Conclusion: Revision PCL reconstruction can improve overall knee function in patients with PCL insufficiency and allow these patients to perform activities of daily living with minimal limitations. However, it should be noted that motion loss and persistent knee laxity is a problem in patients undergoing this procedure. Future studies should focus on long-term follow-up of patients undergoing revision PCL reconstruction in hope of gathering more data on the outcomes and failure rates of these challenging procedures.

Introduction

Posterior Cruciate Ligament (PCL) reconstructions are uncommon knee procedures. Isolated PCL injuries have an annual incidence of 2 cases per 100,000 individuals [1]. Although many isolated PCL injuries do well without surgical intervention, recent literature has shown that PCL reconstructions are increasing because PCL deficiencies can alter strain concentration on the medial and compartments of the knee [2-6]. This ultimately can lead to osteoarthritis and other degenerative changes over time (7). The majority of cases undergoing reconstruction include 68% of patients with multiligamentous knee injuries, and the remaining 32% with high grade isolated PCL tears, and most studies report satisfactory outcomes [8-12]. Some residual posterior laxity is common after PCL reconstruction; however, a systematic review of primary PCL reconstruction found 25 out of 215 (11.6%, range [2.3-30%]) total grafts had failed [4].

The main causes of primary failures leading leading to revision PCL reconstructions (rPCLRs) have been described to be uncorrected posterolateral corner ligamentous instability, misplaced tibial and femoral graft tunnels, osseous malalignments, and primary suture repairs [13,14]. Not all patients with primary graft failure are candidates for revision [13-15]. Due to the decreased number of rPCLRs performed annually, the lack of rPCLRs reported in literature, and the close proximity of neurovascular structures, rPCLRs are often challenging procedures that may lead to unfavorable outcomes and complications [16-18].

The purpose of this study was to systematically review the current literature concerning revision PCL reconstructions. To ameliorate the paucity of literature and lack of knowledge concerning outcomes and complications of patients undergoing a revision PCL reconstruction, we aim to determine the (1) outcomes, (2) complications, and (3) reoperation rates in these patients.

Methods

We performed this study following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [19] literature search was performed using the PubMed and Embase electronic databases to assess all studies published until August 2016. This was done utilizing the following search strings: "PCL [title] OR Posterior [title] AND Cruciate [title]", yielding a total of 1,479 studies. We first excluded 145 articles written in languages other than English. Two investigators (AT and JJ) independently reviewed the title and the abstracts of these articles, and a total of 1282 additional articles were excluded. The studies excluded involved those that evaluated knee arthroplasties, editorials, biomechanical models, basic science articles, cadaveric studies, and studies that only evaluated primary PCLRs.

There remaining 52 articles were cross-referenced in order to avoid missing any studies pertinent to our topic. During this process, three additional studies were found obtaining a total of 55 articles. The full text of these articles was reviewed and we three main criteria for exclusion. The initial 45 studies were excluded because they did not report any revision PCLR cases. An additional five studies were excluded because although revision cases were included in the study, there was no stratification or comparison of data between revisions versus primary reconstruction procedures [10,11, 20-22]. Final study was excluded because although 3 revision cases were present, there was insufficient data on the outcomes of these cases for inclusion in our analysis [18]. Our final cohort consisted of four studies (Figure 1) [13,14,23,24].

The final cohort of four studies documented a total of 56 rPCLRs. Of these, 13 patients were excluded for several reasons: two were lost to follow-up, one had less than 2 months of postoperative follow-up at time of writing, and the remaining ten underwent rPCLR using a technique or graft that was excluded in their respective study. Hence, a total of 43 rPCLRs were computed in our study and we define this as the study cohort.

Since two of the articles included in our final cohort were a single study published in two parts [13,24], we combined the data from the two articles as one study in table 1 and in our detailed analysis. Two additional studies included only revision PCL cases (n=37) [14,24], while the remaining article contained both primary (n=35) and revision (n=6) reconstructions [23]. All articles used in our analysis are classified as Level of Evidence (LOE) IV [25].

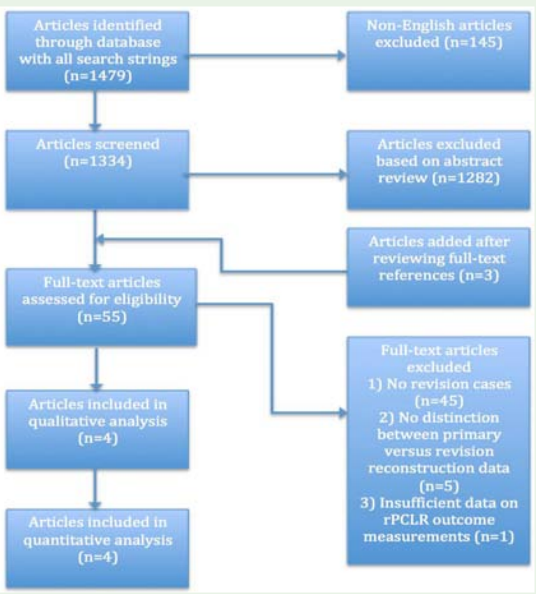

Figure 1: Final cohort consisted of four studies.

All complications were organized into the following categories; neurovascular injury, compartment syndrome, motion loss (arthrofibrosis), osteonecrosis, fractures, persistent laxity, anterior knee pain, ossification, hematoma formation, neuromas, and numbness [16,26]. Our study cohort used various different outcome measurements preoperatively and at the time of the latest follow-up appointment, which included International Knee Documenting Committee (IKDC) scores [27], Tegner activity scale, and The Cincinnati Knee Rating System. Additionally, reported posterior stress radiography, knee testing, Posterior Drawer (PD) examination, and Range of Motion (ROM) were used to assess knee stability.

All data was entered into an electronic spreadsheet (Microsoft Excel, Microsoft Office, and Redmond, Washington). Then, with the use of statistical software (SPSS, IBM Statistics) descriptive statistics was performed for demographic data. Using a random effect model of proportions, the complications, revision, and re-operation rates were determined for patients who underwent rPCLR.

Results

Our final cohort of 43 rPCLRs had a weighted mean age of 31.0 years (range of means 16-64 years), with 78% males (n=61) and 22% females (n=17). The mean length of follow-up following the index procedure was 41.0 months (range 23-84 months). The mean number of months between primary PCL reconstruction and rPCLR was 32.8 months (range 3-187 months) (Table 1).

Two studies identified single and multiple factors described to be causes of primary graft failures of rPCLR cases [13,14]. Both primary suture repairs as well as LCL and posterolateral corner ligamentous deficiencies accounted for 30% of factors identified, and misplaced tibial/femoral tunnels accounted for an additional 17% (Table 2). LCL and posterolateral corner ligamentous deficiencies, ACL deficiencies, misplaced tibial/femoral tunnels, and various osseous malalignments accounted for 23%, 14%, 16%, and 13% of multiple factors identified respectively (Table 3).

Graft type and surgical technique

In terms of the type of graft, there were 24 allografts (55.8%) and 19 autografts (44.2%) utilized among the rPCLR cases. There were 22 Achilles tendon allografts, 15 quadriceps tendon-patellar bone autografts, 4 Bone Patellar Tendon Bone (BPTB) autografts, and 2 BPTB allografts. There were 31 (67%) double bundle reconstructions using a tibial-inlay technique, 6 (13%) transtibial double-bundle reconstructions, and 6 (13%) tibial-inlay single-bundle reconstructions (Table 4) [18].

Concomitant Procedures

Two studies in our cohort reported associated injuries and procedures performed concomitantly with patients undergoing rPCLR [14,24]. There were 12 isolated rPCLRs and 34 associated concomitant procedures, among which 71% (n=24) were PLC procedures. Noyes and Barber-Westin [24] reported concomitant procedures for each individual case, which consisted of 2 PCL + ACL, 2 PCL + PLC, 1 PCL + ACL + PLC, 1 PCL + ACL + MCL, and also reported 8 out of 15 cases had developed abnormal articular cartilage. No differences were found when comparing of the 8 cases with abnormal articular cartilage to the 7 cases with normal articular cartilage. One remaining study also reported associated injuries for both primary and rPCLR cases (Table 4) [18,23].

Table 1: Demographics of revision reconstruction patients.

Authors	Year	LOE	Study Design	Patients (Male, Female)	Revision Cases	Weighted Mean Age, years	Mean Follow-up, months	Time between primary and revision reconstruction, months
Lee et al.	2012	IV	Retrospective Case Series	22 (20, 2)	22	37.4 Range [22-64]	39.6 Range [24-72]	36.3 Range [4-120]
Noyes and Barber-Westin (Part 1 & 2)	2005	IV	Prospective Case Series	15 (10, 5)	15	29 Range [17-49]	44 Range [23-84]	46 Range [4-187]
Cooper and Stewart	2004	IV	Prospective Case Series	41 (31, 10)	6	28 Range [16-44]	39.4	16 Range [3-36]

Table 2: Single causing primary reconstruction failure.

Single Leading to Failure of Primary Graft	Lee et al.	Noyes and Barber-Westin (Part 1 & 2)	Cooper and Stewart
LCL or Posterolateral ligament Deficiency	6	1	NR
MCL Deficiency	0	0	NR
ACL Deficiency	0	0	NR
Misplaced femoral/tibial tunnels	1	3	NR
Varus Osseous Malalignement	0	1	NR
Synthetic Graft Replacements or PCL Thermoplasties	0	1	NR
Obesity	0	0	NR
Traumatic Reinjury	1	1	NR
Tunnel Widening	0	0	NR
Postoperative Infection	1	0	NR
Fixation Failure	0	0	NR
Failure of Revascularization	0	0	NR
Primary Suture Repair	0	7	NR

Table 3: Multiple factors causing primary reconstruction failure.

Multiple Factors Leading to Failure of Primary Graft	Lee et al.	Noyes and Barber-Westin (Part 1 & 2)	Cooper and Stewart
LCL or Posterolateral ligament Deficiency	11	20	NR
MCL Deficiency	2	3	NR
ACL Deficiency	7	12	NR
Misplaced femoral/tibial tunnels	8	14	NR
Varus Osseous Malalignement	2	15	NR
Synthetic Graft Replacements or PCL Thermoplasties	2	6	NR
Obesity	0	7	NR
Traumatic Reinjury	0	4	NR
Tunnel Widening	2	4	NR
Postoperative Infection	0	3	NR
Fixation Failure	0	2	NR
Failure of Revascularization	2	1	NR
Primary Suture Repair	1	6	NR

Table 4: Characteristics of surgical techniques and associated procedures in rPCLRs.

Authors	Tibial-Inlay	Transt-ibial	Single Bundle	Double Bundle	Achilles Tendon Allograft	Quadriceps Tendon-Patellar Bone Autograft	BPTB Auto graft	BPTB Allo graft	Concomitant Procedures and Associated Injuries
Lee et al.	22	0	0	22	22	0	0	0	1 HTO 17 PLC procedures 1 MCLR
Noyes and Barber-Westin (Part 1 & 2)	9	6	0	15	0	15	0	0	1 LCL, Popliteus, and Popliteofibular ligament reconstruction 7 PLC procedures 4 ACLR 1 MCLR 1 Meniscus Repair 1 Meniscus Reconstruction
Cooper and Stewart	6	0	6	0	0	0	4	2	13 Posterolateral instabilities 12 MCL laxity 21 ACL tears

Table 5: Patient reported outcome measurements of revision PCL reconstructions.

Authors	Subjective IKDC Preop (0-100)	Subjective IKDC Postop (0-100)	Objective IKDC Preop	Objective IKDC Postop	Tegner Activity Scale Postop (0-10)	Light sport participation Preop, % (n)	Light sport participation Postop
Lee et al.	39.1	60.4	0 A, 0 B, 6 C, 16 D	2 A, 14 B, 4 C, 2 D	Mean 4.2 Range [2-7]	NR	NR
Noyes and Barber-Westin (Part 1 & 2)	NR	NR	0 A, 0 B, 15 C or D	1 A, 7 B, 6 C, 1D	NR	27 (4)	67 (10)
Cooper and Stewart	NR	82.2 for Revisions, 73.9 for Primaries	0 A, 0 B, 0 C, 6 D	0 A, 3 B, 3 C, 0 D	NR	NR	NR

Reported Outcomes

Outcome scores collected in our cohort of studies consisted of IKDC objective and subjective scores, Tegner activity scale, and return to physical activity and pain using the Cincinnati Knee Rating System (Table 5). Preoperatively, all 43 rPCLRs were objectively scored either as C (abnormal) or D (severely abnormal). Objective postoperative IKDC scores reported for three studies analyzing rPCLR included 3 A (normal), 24 B (nearly normal), 13 C, and 3 D ratings [14,23,24]. Cooper and Stewart also reported a postoperative subjective IKDC score of 82.2 (scale 0-100) in rPCLR cases compared to 73.9 in primary reconstruction cases, but this was not statistically significant [23]. Lee et al [14] reported subjective IKDC scores of 39.1 preoperatively and 60.4 postoperatively.

The Tegner activity scale found that 77% of patients were able to resume activities of daily living as seven patients were rated as 5 (capable of heavy work and exercise), ten as 4, and five as ≤ 3 [14]. Using the Cincinnati Knee Rating system, one study found that 67% of cases had moderate to severe pain with activities of daily living compared to only 13% at the final follow-up appointment. Additionally, 73% of these patients had withdrawn completely from sports activities with the rest participating with limitations, compared to only 33% postoperatively [24,28].

Stability

All studies reported increased stability in knees undergoing rPCLR compared to the preoperative state. Two studies [14,24] had a 6.9 mm combined mean improvement in posterior tibial displacement postoperatively at the latest follow-up. The same two studies also found a combined mean improvement of 5.7 mm using knee and postoperatively [14,24]. Cooper and Steward [23] demonstrated that postoperative mean stress radiography in primary cases was 3.8 mm compared to 6.2 mm in revision cases.

In two studies reporting posterior drawer test results, 100% of preoperative PD examinations were rated either as +3 or +4 (range 0-4) [23,24]. One study reported a mean PD test of 1.3 in revision versus 0.9 in primary reconstructions [23]. In another study, 1 knee had a negative PD exam, 9 knees were evaluated as +1, 5 knees as +2, and 0 knees as +3 or +4 postoperatively [24]. Range of motion measurements were reported in one study describing a mean flexion and extension of 133.5° and 0.8° respectively, compared to 129.6° and 1.2° postoperatively [14]. Additionally, Cooper and Stewart [23] observed a mean 4° flexion loss in reconstructed compared to contralateral knees in both primary and revision cases combined (Table 6).

Complications

Among our cohort of studies, all reported complications [14,23,24] (Table 7). Cooper and Stewart [23] reported 3 posterior hematoma formations in the incision site and 1 case with saphenous nerve distribution numbness, but did not distinguish if these occurred in primary or revision cases. The remaining two studies [14,24] reported a total of 15 complications in 37 rPCLRs (41%). These included 11 cases with significant motion loss still present at the final follow-up appointment, 3 with persistent knee laxity and 1 with an infrapatellar saphenous neuroma requiring excision. None of these 15 complications were intraoperative, which have been commonly reported in PCL reconstruction operations [16,26,29]. Only Noyes and Barber-Westin [20] reported failures of rPCLR, and 2 out of 15 (13.3%) cases were described as a failure with posterior tibial displacement of 9 mm and 10.5 mm on exam (13.3%). Revision failures were defined as knees having greater than an 8 mm increase in posterior tibial displacement found during a posterior drawer test or stress radiography.

Table 6: Knee stability assessments of revision PCL reconstructions.

Authors	Posterior Drawer Test Preop, Grade (n)	Posterior Drawer Test Postop, Grade (n)	Posterior Stress Radiography Preop, Mean (SDV) in mm	Posterior Stress Radiography Postop, Mean (SDV) in mm	ROM Preop, Flexion/ Extension [Range] in°	ROM Postop, Flexion/ Extension [Range] in°	Knee Arthrometer Preop, Mean (SDV) in mm	Knee Arthrometer Postop, Mean (SDV) in mm
Lee et al.	NR	NR	9.9 (±2.8)	2.8 (±1.8)	133.5 [120-145]/0.8 [0-5]	129.6 [120-145]/1.2 [0-5]	7.5 (±2.4)	2.3 (±1.3)
Noyes and Barber-Westin (Part 1 & 2)	All +3 or +4 (9)	0 (1), +1 (9), +2 (5), +3 or +4 (0)	11.7 (±3.0)	5.1 (±2.4)	NR	All knees demonstrated 0-135° of motion at last follow-up	9.1 (±3.3) at 20° Flexion 8.9 (±2.5) at 70° Flexion	2.7 (±3.1) at 20° Flexion 3.3 (±3.9) at 70° Flexion
Cooper and Stewart	+3 (33), +4 (8), Mean 3.5 (Includes Primary PCLR)	0 (9), +1 (25), +2 (7), +3 or +4 (0) Mean for Revision 0.9 and 1.3 for Primary	NR	6.2 for Revision and 3.8 for Primary	NR	134 [115-150]/0 [-3-10] Flexion Loss Compared to Contralateral Knee 4° [0-15] (Includes Primary PCLRs)	NR	NR

Table 7: Complications and failures of revision PCL reconstruction cases.

Authors	Neuro vascular Injury	Osteonecrosis	Significant Motion Loss	Persistent Laxity	Hematoma Formation	Infrapatellar Saphenous Neuroma	Saphenous Nerve Distribution Numbness	rPCLR Failures, % (n)
Lee et al.	0	0	7	2	0	0	0	NR
Noyes and Barber-Westin (Part 1 & 2)	0	0	4	1	0	0	1	13.3 (2)
Cooper and Stewart (Includes Primary PCLRs)	0	0	0	0	**3**	0	**1**	NR

Discussion

Revision PCL reconstructions are extremely rare procedures for multiple reasons. The incidence of PCL injuries that require surgical intervention is low given the good results with the non-operative treatment of many isolated PCL injuries [3,30]. Furthermore, primary PCL reconstruction is a successful procedure for most patients [4,24]. With limited data on rPCLRs, we found a total of 43 rPCLR cases with reported follow-up in the literature. Our main findings were that rPCLRs significantly improved patient outcomes and knee stability, but with a high complication rate of 41%. One study reported failure rates of revision PCL reconstructions (13.3%) similar to that reported in primary PCL reconstructions (2.3-30%) [4,24]. However, there were no reported complications involving neurovascular injury or compartment syndrome among our 43 rPCLR cases.

All studies included in this analysis reported improved objective and patient-reported outcomes, but these improvements were less than reported outcomes in the literature for primary reconstructions [10,33,36]. Cooper and Stewart reported subjective IKDC scores that were slightly higher in revision reconstruction cases (82.2) compared to primary cases (73.9), but they lacked sufficient power to confirm this finding. Furthermore, our analysis indicated that a majority of patients benefited from rPCLR, as 77% to 87% were able to accomplish activities of daily living with minimal limitations and about 53% were able to participate in light sport activities postoperatively. We found that rPCLR cases achieved increased knee stability compared to the preoperative state. There was consistent improvement in knee stability when assessed by stress radiography and/or knee arthrometers [14,24].

The majority of concomitant procedures between the two studies who reported them were PLC procedures (71%) and ACL reconstructions (12%) [14,24]. PLC injuries frequently occur in combination with cruciate ligament injuries, and biomechanical studies have shown that posterolateral corner insufficiency increases the strain on the PCL [31,32]. In accordance with this finding, we have demonstrated that PLC instabilities were determined to be the primary cause of primary graft failure, which could also be the case for revision failures. All the same considerations that go into the primary reconstruction, such as concomitant ligamentous deficiencies and malalignment, must be reassessed when planning the revision. Additionally, assessment and management of prior tunnel placement is important.

This study has several limitations. The studies describing revision PCL reconstructions are performed by a few experienced surgeons in academic centers, making it difficult to generalize results from our study population. Our study cohort is small with variable age groups [16-64]. Although one study also includes primary reconstruction cases, we identified and performed a separate analysis on the revision cases in this study [18,23]. Additionally, the mean length of follow-up was 41 months and therefore we are unable to assess the long-term survival of revision grafts. These factors make it challenging to draw major conclusions from the available data. Furthermore, all studies were level IV, nonrandomized, and lacking a control group.

There is currently no gold standard of care for primary or revision PCL reconstructions [33]. The surgical options to address these issues are extensive and controversial. Clearly, future research is required to determine the ideal reconstruction techniques. The graft choice is highly variable and can depend on a variety of factors, but generally contributes to little variation in functional outcome [12,23,33-35]. Among our cohort of rPCLR cases, there were slightly more allografts than autografts. We found that the majority of revision reconstructions in our study cohort were double-bundle using the tibial-inlay technique. However, some variations existed as Lee et al. described using another modified tibial-inlay technique [14,18,36]. The tibial-inlay technique is commonly used for revision PCL reconstructions with a prior transtibial approach [16,17,24].

There was considerable heterogeneity in postoperative rehabilitation among all studies. Timetables on returning to physical activity, initiating passive knee range of motion exercises, and weight bearing varied significantly. Two studies reported permitting full weight bearing between 4-8 weeks postoperatively [18,23,24]. In two studies, passive ROM exercises were initiated almost immediately at the beginning of the postoperative phase gradually increasing knee flexion from 0-90° during the first 4-6 weeks, with gradual progression in subsequent weeks [14,18,24]. After 2-4 weeks of immobilization at 0°, Cooper and Steward allowed patients to begin passive ROM exercises [23]. Noyes and Barber-Westin allowed return to strenuous activity and athletic at 8-12 months, while the remaining studies did not report on return to physical activity. Variation across studies concerning and number of concomitant procedures could have strongly contributed to the heterogeneity in the reported rehabilitation protocols [33].

Conclusion

Overall, this study shows that revision PCL reconstruction is a reliable procedure to restore posterior stability with good results up to approximately 3 years of follow-up. Outcomes are improved from the preoperative state and most patients return to activities of daily living with minimal limitations. However, based on our results, the outcomes appear to be worse as compared to primary PCL reconstruction. This provides a basis of evidence to support revision reconstruction, but the patient and surgeon must acknowledge the inferior results as compared to the primary reconstruction. While rPCLR has a high rate of complications such as loss of motion and stability, intraoperative neurovascular injury was not reported. Further research regarding outcomes, complications, and failure rates of rPCLRs is needed to gather more data, and to reliably assess the probability of graft failure and complications rates in these patients.

References

1. Sanders TL, Pareek A, Barrett IJ, Kremers HM, Bryan AJ, Stuart MJ, et al. Incidence and long-term follow-up of isolated posterior cruciate ligament tears. Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA. 2016.
2. Parkar AP, Alcala-Galiano A. Rupture of the Posterior Cruciate Ligament: Preoperative and Postoperative Assessment. Seminars in musculoskeletal radiology. 2016; 20: 43-51.
3. Shelbourne KD, Clark M, Gray T. Minimum 10-year follow-up of patients after an acute, isolated posterior cruciate ligament injury treated nonoperatively. The American journal of sports medicine. 2013; 41: 1526-1533.
4. Hammoud S, Reinhardt KR, Marx RG. Outcomes of posterior cruciate ligament treatment: a review of the evidence. Sports medicine and arthroscopy review. 2010; 18: 280-291.
5. Gao SG, Zhang C, Zhao RB, Liao Z, Li YS, Yu F, et al. Effect of partial and complete posterior cruciate ligament transection on medial meniscus: A biomechanical evaluation in a cadaveric model. Indian journal of orthopaedics. 2013; 47: 493-499.
6. Pearsall AWt, Hollis JM. The effect of posterior cruciate ligament injury and reconstruction on meniscal strain. The American journal of sports medicine. 2004; 32: 1675-1680.
7. Logan M, Williams A, Lavelle J, Gedroyc W, Freeman M. The effect of posterior cruciate ligament deficiency on knee kinematics. The American journal of sports medicine. 2004; 32: 1915-1922.
8. Wang CJ, Chen HS, Huang TW, Yuan LJ. Outcome of surgical reconstruction for posterior cruciate and posterolateral instabilities of the knee. Injury. 2002; 33: 815-821.
9. Wang D, Berger N, Cohen JR, Lord EL, Wang JC, Hame SL. Surgical treatment of posterior cruciate ligament insufficiency in the United States. Orthopedics. 2015; 38: 281-286.
10. Martinek V, Steinbacher G, Friederich NF, Muller WE. Operative treatment of combined anterior and posterior cruciate ligament injuries in complex knee trauma: can the cruciate ligaments be preserved? The American journal of knee surgery. 2000; 13: 74-82.
11. Mariani PP, Margheritini F, Camillieri G. One-stage arthroscopically assisted anterior and posterior cruciate ligament reconstruction. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2001; 17: 700-707.
12. Chen CH, Chen WJ, Shih CH. Arthroscopic reconstruction of the posterior cruciate ligament: a comparison of quadriceps tendon autograft and quadruple hamstring tendon graft. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2002; 18: 603-612.
13. Noyes FR, Barber-Westin SD. Posterior cruciate ligament revision reconstruction, part 1: causes of surgical failure in 52 consecutive operations. The American journal of sports medicine. 2005; 33: 646-654.
14. Lee SH, Jung YB, Lee HJ, Jung HJ, Kim SH. Revision posterior cruciate ligament reconstruction using a modified tibial-inlay double-bundle technique. The Journal of bone and joint surgery American volume. 2012; 94: 516-22.
15. Johnson DH, Fanelli GC, Miller MD. PCL 2002: indications, double-bundle versus inlay technique and revision surgery. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2002; 18: 40-52.
16. Zawodny SR, Miller MD. Complications of posterior cruciate ligament surgery. Sports medicine and arthroscopy review. 2010; 18: 269-274.
17. Mauro MA, Jaques PF, Moore M. The popliteal artery and its branches: embryologic basis of normal and variant anatomy. AJR American journal of roentgenology. 1988; 150: 435-437.
18. Mariani PP, Margheritini F. Full arthroscopic inlay reconstruction of posterior cruciate ligament. Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA. 2006; 14: 1038-1044.
19. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Annals of internal medicine. 2009; 151: 264-269.
20. Jung TM, Lubowicki A, Wienand A, Wagner M, Weiler A. Knee stability after posterior cruciate ligament reconstruction in female versus male patients: a prospective matched-group analysis. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2011; 27: 399-403.
21. Noyes FR, Barber-Westin S. Posterior cruciate ligament replacement with a two-strand quadriceps tendon-patellar bone autograft and a tibial inlay technique. The Journal of bone and joint surgery American volume. 2005; 87: 1241-1252.
22. Owesen C, Sivertsen EA, Engebretsen L, Granan LP, Aroen A. Patients With Isolated PCL Injuries Improve From Surgery as Much as Patients With ACL Injuries After 2 Years. Orthopaedic journal of sports medicine. 2015.
23. Cooper DE, Stewart D. Posterior cruciate ligament reconstruction using single-bundle patella tendon graft with tibial inlay fixation: 2- to 10-year follow-up. The American journal of sports medicine. 2004; 32: 346-360.
24. Noyes FR, Barber-Westin SD. Posterior cruciate ligament revision reconstruction, part 2: results of revision using a 2-strand quadriceps tendon-patellar bone autograft. The American journal of sports medicine. 2005; 33: 655-665.
25. Marx RG, Wilson SM, Swiontkowski MF. Updating the assignment of levels of evidence. The Journal of bone and joint surgery American volume. 2015; 97: 1-2.
26. Shahrulazua A, Rafedon M, Mohd Nizlan MN, Sullivan JA. Delayed compartment syndrome of leg and foot due to rupture of popliteal artery pseudoaneurysm following posterior cruciate ligament reconstruction. BMJ case reports. 2014.
27. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating Scale (ARS), and Tegner Activity Score (TAS). Arthritis care & research. 2011; 63: 208-228.
28. Barber-Westin SD, Noyes FR, McCloskey JW. Rigorous statistical reliability, validity, and responsiveness testing of the Cincinnati knee rating system in 350 subjects with uninjured, injured, or anterior cruciate ligament-reconstructed knees. The American journal of sports medicine. 1999; 27: 402-416.
29. Osti M, Hierzer D, Seibert FJ, Benedetto KP. The Arthroscopic All-Inside Tibial-Inlay Reconstruction of the Posterior Cruciate Ligament: Medium-Term Functional Results and Complication Rate. The journal of knee surgery. 2016.
30. Schulz MS, Russe K, Weiler A, Eichhorn HJ, Strobel MJ. Epidemiology of posterior cruciate ligament injuries. Archives of orthopaedic and trauma surgery. 2003; 123: 186-191.
31. Wang CJ, Chen CY, Chen LM, Yeh WL. Posterior cruciate ligament and coupled posterolateral instability of the knee. Archives of orthopaedic and trauma surgery. 2000; 120: 525-528.
32. Markolf KL, Wascher DC, Finerman GA. Direct in vitro measurement of forces in the cruciate ligaments. Part II: The effect of section of the posterolateral structures. The Journal of bone and joint surgery American volume. 1993; 75: 387-94.
33. Chen CH. Surgical treatment of posterior cruciate ligament injury. Chang Gung medical journal. 2007; 3: 480-492.

34. Hoher J, Scheffler S, Weiler A. Graft choice and graft fixation in PCL reconstruction. Knee surgery, sports traumatology, arthroscopy: official journal of the ESSKA. 2003; 11: 297-306.

35. Ahn JH, Yoo JC, Wang JH. Posterior cruciate ligament reconstruction: double-loop hamstring tendon autograft versus Achilles tendon allograft-clinical results of a minimum 2-year follow-up. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2005; 21: 965-969.

36. Jung YB, Jung HJ, Tae SK, Lee YS, Yang DL. Tensioning of remnant posterior cruciate ligament and reconstruction of anterolateral bundle in chronic posterior cruciate ligament injury. Arthroscopy: the journal of arthroscopic & related surgery: official publication of the Arthroscopy Association of North America and the International Arthroscopy Association. 2006; 22: 329-338.