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Original article

Retrospective cohort study comparing postoperative joint stability between all-inside PCL reconstruction technique and conventional PCL reconstruction technique in patients with multiligament knee injury

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ABSTRACT

Objectives: The purpose of our study was to compare (1) posterior cruciate ligament (PCL) laxity, (2) patient-reported outcome, and (3) complications after the all-inside PCL reconstruction (Al-PCLR) technique and conventional PCLR (CON-PCLR) technique at minimum 2-year follow-up. We hypothesized that AI-PCLR and CONV-PCLR would yield similar results in PCL laxity, patient-reported outcomes, and complications.

Method: A retrospective cohort study was conducted on patients who underwent PCLR with the Al-PCLR technique and CON-PCLR technique from 2012 to 2023 in a single hospital. Medical records were reviewed for patients' demographic data, the technique of PCL reconstruction and complications. Patient-reported outcome scores, including International Knee Documentation Committee (IKDC), Tegner activity scale, and Lysholm score, as well as bilateral kneeling radiographs and physical examinations, were collected at least 2 years postoperatively.

Results: Included in the study were 24 patients: 11 who underwent the CON-PCLR technique (mean age 40.7 +years) and 13 who underwent Al-PCLR (mean age 34.3 + 12.9 years). Three patients in AI-PCLR group were lost to follow-up and one patient is the CON-PCLR group, a revision case, was excluded from the study.

Bilateral stress kneeling radiographs showed a similar side-to-side difference between two groups (CON-PCLR vs AL-PCLR: mean 7.5 ± 5.2 vs 5.8 ± 4.8 mm; P = 0.38) There were no statically significant differences between the two groups in postoperative IKDC (CON-PCLR vs AL-PCLR: 68.9 vs 73.9; P = 0.37), Lysholm (89.1 vs 94.1; P = 0.42), or Tegner activity (6 vs 6.4; P = 0.68) scores.

Conclusion: All-inside PCLR demonstrates comparable stability to Conventional PCLR, with satisfactory patient-report outcome at minimum 2 years follow up and low rate of complications in patients with multiligament knee injury.

Level of evidence: III Retrospective comparative study.

1. Introduction

The posterior cruciate ligament (PCL) is the strongest ligament of the knee, play an important role in knee stability. PCL injuries are fewer common injuries and usually associated with anterior cruciate ligament (ACL), medial collateral ligament (MCL), posterolateral corner (PLC) and meniscus torn. Long-term follow up showed higher rate of arthrosis due to abnormal biomechanics and increased rate of meniscus tears.[1–3]

The PCL has self-healing potential, especially in acute isolated grade I or II PCL injuries that undergo nonoperative treatment.[4,5] As for high-grade PCL injuries, when conservative fails, and in the case of multiple ligament injury, PCL reconstruction (PCLR) is the standard treatment.[6,7]

The current literature on clinical outcomes after PCL reconstruction in multiligament knee injuries concludes that normal knee stability was not fully restored but significantly improved in clinical symptom, functional scores, and posterior knee laxity.[8] In the present study, it was found that after PCL reconstruction, posterior laxity increased over time during stress radiographs.[9] A recent systematic review showed that no difference in clinical outcomes between single versus double bundle PCL

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reconstruction but demonstrated superior results biomechanical studies in double-bundle PCL reconstruction group.[10,11]

A variety of PCLR techniques are used to reconstruct PCL, including conventional and all-inside methods. The all-inside posterior cruciate reconstruction all-inside posterior cruciate ligament reconstruction (AI-PCLR) involves creating a closed socket and using adjustable suspensory fixation on both the femur and tibia. This technique offers advantages in terms of a large graft diameter, shorter length with strong fixation, preservation of more bone stock, reduced killer turn, easier tension adjustment, and fewer screw-related suture problems. These factors suggest a potential benefit in addressing posterior knee laxity post-operatively.[12–14] However, only a few studies have reported outcomes comparing conventional PCLR (CONV-PCLR) and AI-PCLR.

The purpose of our study was to compare (1) PCL laxity, (2) patient-reported outcomes, and (3) complications after the all-inside PCL reconstruction (Al-PCLR) technique and conventional PCLR conventional posterior cruciate ligament reconstruction (CON-PCLR) technique with a minimum 2-year follow-up. We hypothesized that AI-PCLR and CONV-PCLR would yield similar results in PCL laxity, PROs, and complications.

2. Methods

This retrospective study was approved by the institute Review Board at Chaoprayayomraj Hospital (Approval number YM009/2566) to search for the database of patients who underwent PCLR from 2012 to 2022. Throughout the study period, all surgery was performed by a single orthopedic surgeon. Inclusion criteria consisted of patients who (1) underwent PCLR with a hamstring graft and (2) had adequate follow-up for radiographic, patient-reported outcomes (PROs) and complications. Exclusion criteria consisted of (1) revision PCLR (2) follow-up less than 2 years (3) pre-existing osteoarthritis with Kellgren and Lawrence (KL) grade $\geq$3 in the knee.

Each patient's electronical data, including demographic information, operative note and MRI findings, was manually reviewed. Patients were contacted by telephone and scheduled for appointments when necessary.

3. Surgical technique

After regional anesthesia with spinal nerve block, arthroscopic examination was conducted first to confirm the diagnosis based on the physical examination and MRI. A quadruple-loop semitendinosus tendon autograft, combined with a contralateral semitendinosus autograft, and adding gracilis tendon graft if necessary to achieve a final length approximately 80 mm and a diameter of more than 8 mm, was used for all PCLRs (see Fig. 1). The gracilis tendon was prepared for posterolateral corner reconstruction using either modified Larson technique[27] or the arthroscopic popliteus reconstruction technique, and it was fixed with a Bio-Composite interference screw (Arthrex) at the femoral attachment of the popliteal tendon[15,16]

For AI-PCLR, the femoral socket was prepared using an antegrade low-profile reamer to ream the femoral socket to a length of about 20 mm. In AI-PCLR, the tibial socket was retrograde drilled using the anatomical PCL tibial Guide (Arthrex) and FlipCutter (Arthrex), then fixed with a double suspensory mechanism using TighRope (Arthrex) for the femoral socket and TighRope ABS(Arthrex) for the tibial socket. (see Figs. 2 and 3).[12–14,17]

For CON-PCLR, the femoral and tibial sockets were reamed antegradedly using a low-profile reamer, then fixed with TighRope(Arthrex) for femoral socket and a Biocomposite interference screw with suture to the post on the tibial socket.[611] Posterolateral corner reconstruction was performed before tensioning TighRope (Arthrex) with ABS button on the tibial side. The knee underwent cyclic loading, flexed and extended, after which the entire constructed was tensioned in 90-degree flexion with an anterior drawer position. Retention was performed on both the femoral and tibial end before concluding the operation.

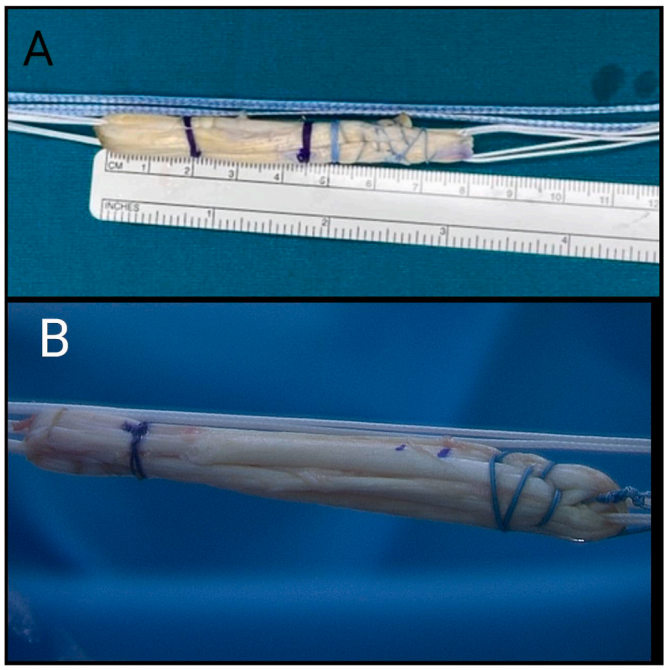

Fig. 1. Illustrates graft preparation for all-inside PCL reconstruction. (A) The graft is prepared to be approximate 8 cm in length, with (B) femoral side attach to TighRope with a button (Arthrex, Naples, Fl) while the tibial side is attached to a TighRope without a button (Arthrex, Naple, Fl).

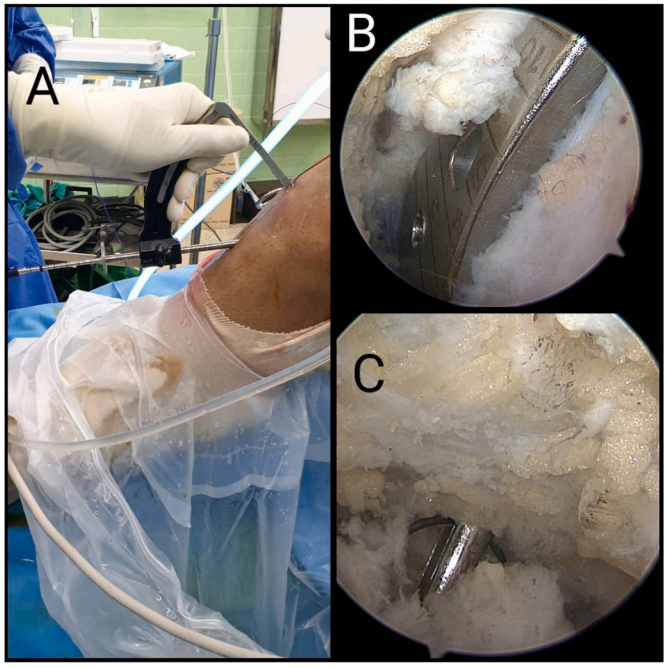

Fig. 2. Illustrates the method of tibial tunnel preparation for all-inside PCL reconstruction. (A) Retrograde reaming with FlipCutter (Arthrex, Naple, FL) was performed through anteromedial portal, and the length of reaming should be less than the measured length of the tibial tunnel. (B) Arthroscopic view from the posteromedial portal shown the PCL footprint , with the tibial PCL aiming device guarding neurovascular bundle. (C) A beath pin is inserted with the passing suture through the tibial tunnel that was created.

The postoperative rehabilitation program involved immobilization in a full extension brace or slab for the first 6 weeks with partial weight-

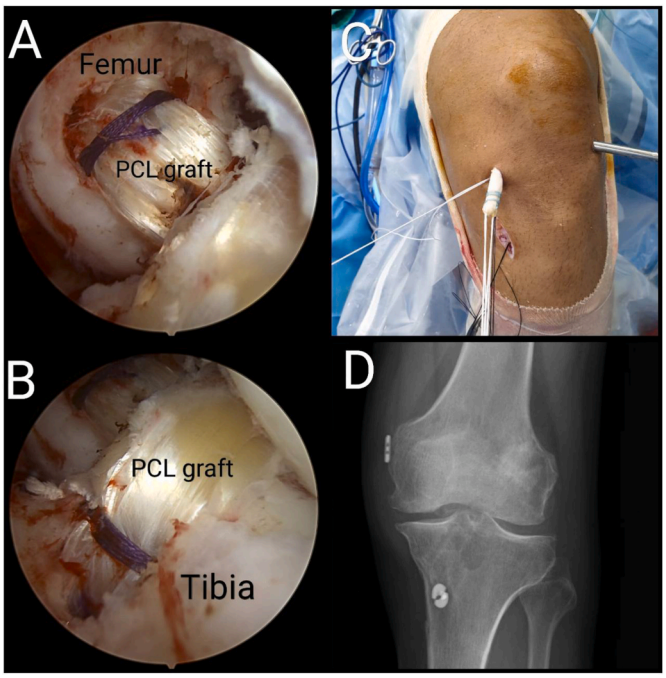

Fig. 3. Illustrates the PCL graft passing through the anteromedial portal: (A) PCL graft passed to the femoral socket first, (B) PCL graft passing through the tibial socket, (C) graft passing through the anteromedial portal, and (D) postoperative radiograph.

bearing. After that, the knee brace was gradually adjusted every 2 weeks until achieving full range of motion. The knee brace was continued until 3 months postoperatively.

4. Outcome evaluation

Patients' electronic data were reviewed to obtain demographic information, preoperative examination details, associated ligament injuries, grade of knee dislocation (KD), operative procedures, time to operation, time to evaluation, complications, patient-reported outcome (PROs) including International Knee Documentation Committee (IKDC) scores, Tegner activity scale and Lysholm score.[18] If necessary, patients were contacted for follow-up via telephone.

PCL laxity was assessed by a single radiologist, measuring the side-to-side difference (SSD) on postoperative bilateral kneeling stress radiograph with single-leg full weight-bearing (see Fig. 4).[19]

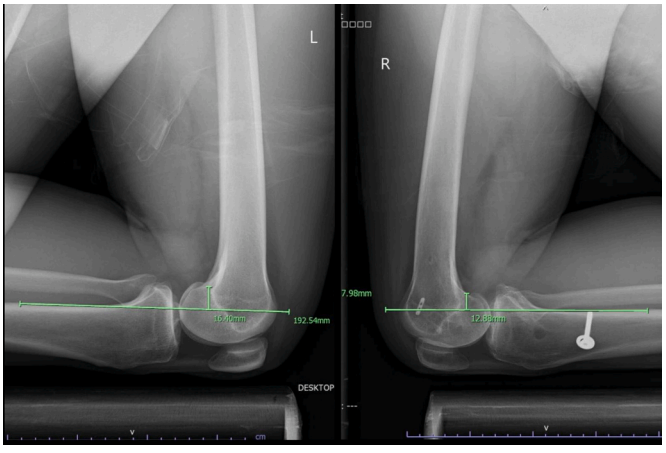

Fig. 4. Displays a bilateral stress kneeling radiograph that calculates the side-to-side difference.

PCLR failure was defined as graft rupture when PDT laxity was greater than grade 2 or SSD exceeded 10 mm, confirmed by PCL graft rupture on MRI.

5. Statistical analysis

Patients' characteristics, including demographic data, time from injury to surgery, time from surgery to radiographic examination, complication rate and outcomes, were analyzed using descriptive statistics, including mean, standard deviation, and percentage. Continuous data were assessed using Student *t* tests. Statistical significance was defined as $P < 0.05$.

6. Result

A total of 24 patients who underwent PCLR between 2012 and 2022 were identified. Among these patients, 4 were excluded from the study: 1 underwent revision PCLR, and 3 were lost to follow-up. Consequently, 20 patients were eligible for analysis in the study, with 10 patients in AI-PCLR and 10 patients in CONV-PCLR group, all having a minimum follow-up of more than 2 years and meeting inclusion criteria. Demographic data are presented in Table 1. There were no significant differences between the two groups in terms of patient characteristics. The time to reconstruction was 8.6 months (range 3–36) in CON-PCLR versus 6.5 months (range, 5–12) in AI-PCLR ($P > 0.05$). In CON-PCLR group, 7 cases (70 %) were KD type 3 and 3 case (30 %) were KD 4 while in the AI-PCLR group, 9 case (90 %) were KD type 3 and 1 case was KD type 4, with no KD type 1 and 2 in either group. Patient injury characteristics and additional procedures were not different between the two groups. Each case included additional posterolateral corner reconstruction using either the modified Larson technique or arthroscopic popliteal reconstruction (see Table 2).

There was no statistically significant difference in postoperative PROs between both groups. The postoperative IKDC score (CON-PCLR vs AL-PCLR: 68.9 vs 73.9; P = 0.37), Lysholm (89.1 vs 94.1; P = 0.42), or Tegner activity (6 vs 6.4; P = 0.68) scores showed no significant distinctions. Bilateral kneeling stress radiographs indicated that the mean SSD in CON-PCLR was 7.5 mm, and the mean SSD in AI-PCLR was 5.8 mm, with no significant difference ($P > 0.05$). Two patients in the CON-PCLR group underwent reoperation one due to the interference screw of posterolateral corner reconstruction being prominent and needing removal, and the other due to a ruptured PCL graft requiring revision PCL reconstruction; there were no infections in either group. The latest follow-up mean was 89.5 months in the CON-PCLR group and 57.5 months in the AI-PCLR group (see Table 3).

Table 1
Patients characteristics.

Characteristics	*Con PCLR (n = 10)*	*AI PCLR (n = 10)*	P
Age, y	40.7 ± 12	34.3 ± 12.9	0.31
Body mass index	24.7 ± 3.8	24.4 ± 5.7	0.90
Sex			0.53
male	8(80)	9(90)	
female	2(20)	1(10)	
Time to reconstruction, mo. (range)	8.6(3–36)	6.5(5–12)	0.54
KD grade			0.26
KD1	0	0	
KD2	0	0	
KD3	7(70)	9(90)	
KD4	3(30)	1(10)	
Clinical follow-up, Mo (range)	89.5 ± 40.4 (24–120)	57.5 ± 33.4 (24–96)	0.70

[a] Data are expressed as mean ± SD (95 % CI) or n (%). P value indicates statistically significant difference between groups (P < 00.05).

Table 2
Patient Injury Characteristics, PCL graft size and Additional Procedures[a].

Characteristics	Con PCLR (n = 10)	AI PCLR (n = 10)	P
Meniscal injury	1(10)	1(10)	>0.99
Meniscal repair or partial meniscectomy	1(10)	1(10)	>0.99
Chondral lesion	2(20)	3(30)	>0.99
Peroneal nerve injury	1(10)	0(0)	>0.99
PCL graft size (mm.)			0.63
8	6(60 %)	8(80 %)	
9	4(40 %)	2(20 %)	
ACL reconstruction	1(10)	0(0)	>0.99
MCL/PMC repair/reconstruction	1(10)	0(0)	>0.99
LCL/PLC repair/reconstruction			0.07
LCL repair	0(0)	1(1)	
Modified Larson	8(80)	3(30)	
Popliteus reconstruction	2(20)	6(60)	

[a] Data are expressed as n (%). ACL, anterior cruciate ligament; MCL, medial collateral ligament; LCL, lateral collateral ligament; PCL, posterior cruciate ligament; PLC, posterolateral corner; PMC, posteromedial corner.

Table 3
Patients Outcomes at final follow-up[a].

Outcome	*Con PCLR (n = 10)*	*AI PCLR (n = 10)*	*P*
IKDC score	68.9 ± 11	73.9 ± 10	0.37
Lysholm score	89.1 ± 18.2	94.1 ± 9.4	0.42
Tegner score	6 ± 1.9	6.4 ± 1.8	0.68
Side-to-side difference, mm	7.5 ± 5.2	5.8 ± 4.8	0.31
Time to radiographic, Mo (range)	89.5 ± 40.4	57.5 ± 23.4	0.70
Complication			
Graft failure	0	0	>0.99
Infection	0	0	>0.99
Reoperations	2	0	0.47

[a] Data are expressed as mean ± SD (95 % CI) or n (%). P value indicates a statistically significant difference between group ($P < 0.05$). IKDC, International Knee Documentation Committee.

7. Discussion

The primary finding of our study was that AI-PCLR demonstrated good clinical outcomes, a low complication rate, and a reoperation rate comparable to the conventional technique. Postoperative laxity, evaluated by bilateral stress radiograph in kneeling position at a minimum 2 years, was similar in both groups.

Knee dislocation with multiple ligaments is often a challenging problem in some countries due to lack of allograft tissue. In our practice, we adopt a stage procedure, repairing collateral ligaments to limit the use of soft tissue grafts for future reconstruction. After the healing of collateral ligaments and achieving a full range of motion, we proceed with the reconstruction of ACL and PCL. However, persistent posterior laxity is a common finding after PCLR, especially in case of high-grade knee dislocation.[20] Various causes contribute to this laxity, including missed associated ligament injuries, technical issues, tunnel malposition, small graft size, insecure fixation, and overly aggressive postoperative rehabilitation. Interference screws are used for fixation in both femoral and tibial tunnels to stabilize the PCL graft, with the challenge of placing the screw between the bone-graft interface, particularly on the tibial side. Proper positioning involves having the screw tip just at the opening on the posterior tibial cortex. Complication can occur during the final stages of operation, such as the screw lacerating the graft passing suture, graft laceration, or the screw being embedded in the PCL graft tissue, resulting in an unstable construct and laxity in the end.[21–23]

The AI-PCL technique was developed to offer advantage of safety, reproducibility, eliminate of the "killer turn" problem, bone preservation, and retention technique. However, concern remain about bone tunnel widening, stability and elongation of the construct.[24] Although there is limited evidence on this topic, the available literature on all-inside ACL reconstruction suggests that it may have better functional outcome and less tunnel widening compared to the complete tunnel ACL reconstruction technique.[25]

Studies by Hui et al. and Erik et al. demonstrated varying outcome in severe posterior and posterolateral rotatory instability after PCL and posterolateral corner reconstruction, with mean SSD at 2 years postoperatively ranging from 4.6 ± 3.2 mm to 2.6 ± 0.6 mm, respectively.[20,26]

Our study's result indicated the SSD of 7.5 ± 5.2 mm in CON-PCLR group and 5.8 ± 4.8 mm in the AI-PCLR group ($P = 0.307$). Although the AI-PCLR group exhibited slightly better SSD compared to CON-PCLR, this difference lacked statistical significance. These findings support the potential benefit of AI-PCLR. The report PROs were comparable to previously reported data. Mean SSD in our study was worse compared to previous data, likely due to most of the cases involving high-energy trauma, with at least a KD 3 severity of injury, making the degree of injury severe. Additionally, varying time from injury to surgery, some exceeding 1 year, may have contributed to poor surgical outcomes than in cases with earlier intervention. The PCL graft size was smaller compared to previous studies due to a lack of allograft availability.

8. Limitation

This study is limited by the relatively small number of cases, as PCL injury is uncommon, even though we collected data from a 10-years period. The patient population exhibits variability in terms of the grade of knee dislocation, associated injuries, and the technique used for additional posterolateral corner reconstruction. A multicenter study is necessary to increase the number of cases in the future.

9. Conclusions

At minimum 2-year follow-up, all-inside PCLR demonstrated comparable patient-reported outcomes (PROs) and stability to conventional PCLR, with low complication and reoperation rate.

Institutional review board statement

This study was approved by the Ethics Committee of the Chaoprayayomraj Hospital (Approval number YM009/2566)

Informed consent statement

The requirement for individual consent was waived by the committee.

Data sharing statement

No additional data is available.

Authors contributions

TB was carried out to create ideas, manuscript writing and data curation. NB participated in performing the radiographic measurements. TI participated in performed statistical analysis, reviewed, wrote, and edited the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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