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RESEARCH

Single-bundle vs. double-bundle isolated posterior cruciate ligament reconstruction: a retrospective cohort study on time to work and functional outcomes

Rodrigo Olivieri[1,2] · Marco Koch[1,3] · José Tomás Muñoz[1,3] · Tania Rojas[1,2] · Jaime Ugarte[1,2] · José Laso[1,2] · Nicolás Gaggero[1,2] · Nicolás Franulic[1,3]

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Abstract

Purpose The optimal surgical technique for posterior cruciate ligament (PCL) reconstruction remains debated, especially among patients under workers' compensation. Biomechanical studies suggest double-bundle (DB) reconstruction provides superior stability compared to single-bundle (SB), but clinical evidence is inconclusive. The aim of this study is to compare return-to-work time, functional outcomes, and complication rates between SB and DB PCL reconstruction (PCL-R) in patients with work-related knee injuries.

Methods We conducted a retrospective, non-concurrent cohort study of patients with isolated PCL injuries covered by workers' compensation who underwent SB or DB PCL-R between 2019 and 2022. Time to return to work, functional outcomes (KOOS, Lysholm), and postoperative complications were analysed and compared between groups.

Results A total of 22 patients were included (14 in SB, 8 in DB). The median return-to-work time was 176.5 days, with no significant difference between the groups ($p = 0.516$). No statistically significant differences were found in complication rates or functional scores (KOOS and Lysholm) between the 2 techniques. The small sample size ($n = 22$) reflects the low incidence of isolated PCL injuries.

Conclusion In workers with isolated PCL injuries, SB and DB PCL-R yielded comparable return-to-work times and functional outcomes. Although DB reconstruction may offer biomechanical advantages, these did not translate into statistically significant clinical differences in this cohort. These findings support the use of either technique in occupational settings, where timely functional recovery is crucial.

Level of evidence Retrospective study of non-concurrent cohorts (Level III).

Keywords Posterior cruciate ligament · Reconstruction · Single-bundle · Double-bundle · Workers' compensation

✉ Rodrigo Olivieri
rodrigoolivieri@gmail.com

Marco Koch
makoch@miuandes.cl

José Tomás Muñoz
jtmunoz@miuandes.cl

Tania Rojas
lizcorg15@gmail.com

Jaime Ugarte
jignaciougarte@gmail.com

José Laso
jignaciolaso@gmail.com

Nicolás Gaggero
nicolasgaggero@gmail.com

Nicolás Franulic
nicofranulic02@gmail.com

[1] Knee Unit, Orthopaedic Department, Hospital del Trabajador, Santiago, Chile

[2] Universidad Andrés Bello, Hospital del Trabajador, Facultad de Medicina, Andrés Bello National University, Santiago, Chile

[3] Facultad de Medicina, Universidad de Los Andes, Chile, Santiago, Chile

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Introduction

Acute posterior cruciate ligament (PCL) injuries account for 3% to 38% of acute knee ligament injuries [1, 2]; however, isolated PCL injuries are uncommon, with an estimated annual incidence of 2 per 100,000 [3, 4]. The PCL is the strongest ligament in the knee [5, 6] and serves as the primary restraint against posterior tibial translation, providing approximately 90% of resistance across most of the knee's range of motion [6, 7]. The PCL originates on the lateral aspect of the medial femoral condyle and inserts on the posterior-lateral tibial plateau, with an average length of 38 mm and a mean diameter of 13 mm in its midportion [8–10]. Structurally, it is generally composed of the larger anterolateral (AL) bundle and the smaller posteromedial (PM) bundle [9, 10]. These two bundles exhibit distinct tension patterns across the knee's range of motion, with the AL bundle under greater tension in flexion and the PM bundle more tense in extension [9, 11, 12].

Historically, nonoperative management of PCL injuries showed good to excellent outcomes [13]; however, later studies associated non-operative PCL injury management with a progressive decline in clinical scores and earlier onset of osteoarthritis [14, 15]. Consequently, surgical treatment of symptomatic complete PCL injuries has gained traction [16, 17]. In this context, various PCL reconstruction (PCL-R) techniques have been described, including single-bundle (SB) and double-bundle (DB) restoration approaches [18–21].

Several cadaveric and biomechanical studies have compared graft kinematics, stability, and strength between SB and DB reconstruction techniques for PCL-R, concluding that DB better restore biomechanical function [12, 18, 22, 23]. However, evidence remains controversial when assessing the clinical and radiological outcomes of both techniques, with some studies have reported no significant differences between SB and DB PCL-R [19–21, 24] and others showing improved clinical outcomes with the DB technique [25–27].

In this context, we have observed that clinical evidence primarily pertains to athletes, and the limited literature on PCL injuries in workers mainly involves military populations [28, 29], leaving a significant knowledge gap regarding outcomes in civilian workers, particularly those covered under workers' compensation. This population presents unique characteristics, including higher physical demands, variable return-to-work expectations, and potential medico-legal implications that can influence recovery timelines and outcomes. To the best of our knowledge, this is the first study comparing SB and DB PCL-R techniques in a civilian working cohort with isolated PCL injuries. Understanding how these techniques compare in terms of return-to-work time and functional recovery is essential, especially for patients engaged in labour-intensive occupations, where timely and effective rehabilitation is crucial for both clinical and occupational reintegration.

This study aimed to characterize the population undergoing SB or DB PCL-R at a single trauma center serving patients with workers' compensation and to compare clinical outcomes, complications, and return-to-work times between both groups. The authors hypothesized that clinical outcomes and return-to-work times would not differ between the two techniques.

Materials and methods

Human ethics and consent to participate

The study was conducted in compliance with the Declaration of Helsinki and ethical guidelines for medical research involving human subjects. Approval was obtained from the Institutional Ethics Committee (internal code CEC/12/2024), and written informed consent was secured from all participants. No animals were involved in this research.

Study design

A retrospective, non-concurrent cohort study was conducted by analyzing records of patients with isolated PCL rupture, aged over 18 years, who underwent surgical treatment at a single level-I trauma center. The evaluated patients were covered under the institution's occupational insurance, representing a captive population without follow-up losses.

The institutional database of electronic medical records for patients who underwent isolated PCL-R using SB or DB techniques with autografts or allografts between 2019 and 2022 was reviewed retrospectively.

Demographic characteristics, time elapsed from PCL diagnosis to surgery, complications, return-to-work time, and postoperative follow-up outcomes were recorded, including infection, stiffness, chronic pain, reconstruction failure, need for reoperation, and final range of motion (ROM) at discharge as documented during the last follow-up. A minimum follow-up period of 2 years post-surgery was ensured. Return-to-work time was defined as the number of days elapsed from PCL reconstruction surgery to the patient's return to the same employment held prior to the injury. This definition refers to a full-duty return to the original position. Return-to-work status was verified at a follow-up visit 3 months after discharge, as all patients in this study were treated under the national occupational injury insurance system, which ensures lifelong follow-up and documentation of any sequelae or work-related limitations.

Functional outcomes were assessed 2 years post-surgery using patient-reported outcome measures (PROMs) specific to knee injuries. The Knee Osteoarthritis Outcome Score (KOOS) and the Lysholm score were utilized to evaluate functionality and disability associated with these injuries.

A two-year follow-up period was defined as adequate and safe for diagnosing complications prior to the final evaluation. During this period, patients were assessed monthly for the first three months, followed by biannual evaluations. All surgeries were performed by 4 surgeons from the responsible team.

Relevant data from the initial clinical evaluation of patients were collected, including posterior tibial translation measurements using specific functional tests for PCL injuries. Posterior tibial translation was classified into four grades according to the International Knee Documentation Committee (IKDC) classification system [30]: grade 0 (0 to 2 mm translation), grade I (3 to 5 mm), grade II (6 to 10 mm), and grade III (greater than 10 mm). Posterior drawer tests were used to assess PCL stability, while valgus-varus stress tests, anterior drawer tests, Lachman tests, and dial tests were employed to rule out associated injuries.

Additionally, preoperative and postoperative outcomes were recorded, including reviews of radiographic imaging (plain radiographs, long-leg radiographs, and posterior drawer stress radiographs of both knees) and magnetic resonance imaging (MRI). The primary focus of the review was on assessing PCL stability and functionality, as well as adjacent ligamentous structures, before and after surgery.

Inclusion and exclusion criteria

Patients aged over 18 years with MRI-confirmed complete PCL rupture who underwent isolated PCL-R with SB or DB techniques using autografts or allografts at our institution were included. Surgical indications included:

- Patients with grade III posterior drawer according to IKDC classification and posterior drawer stress radiographs showing posterior tibial translation ≥ 8 mm compared to the contralateral limb, as measured using the standardized technique described by Jackman et al. [31].
- Patients with grade II posterior drawer according to IKDC classification who failed nonoperative management, including physical therapy and PCL bracing, for a minimum of four months.

Exclusion criteria included patients requiring PCL-R as part of multiligament surgeries (classified as KD grade 1 to 5 according to Schenck [32]), revision PCL surgeries, associated lower limb fractures, and patients who received synthetic augmentation with tape-like sutures.

Given the retrospective and non-randomized design of this study, there is a potential risk of selection bias and confounding. The choice between SB and DB reconstruction was made at the discretion of the operating surgeon, based on anatomical considerations, graft availability, and individual surgical preference. While this reflects routine clinical practice, it may introduce allocation bias. Furthermore, the retrospective nature of the study limits control over all variables and precludes establishing causality between surgical technique and clinical outcomes.

Surgical technique

Single bundle transtibial PCL reconstruction

The patient is positioned in a supine position and a non-sterile tourniquet is placed on the upper thigh. After performing physical examination, the injured limb is prepared and draped into sterile fields. A standard anterolateral (AL) and anteromedial (AM) portals are made immediately adjacent to the patellar tendon to maximize notch and posterior compartment visualization. Then a conventional diagnostic arthroscopy is conducted using a standard 30° arthroscope. The PCL remnant is debrided utilizing a shaver and a radiofrequency ablation device. Our preference is to preserve the meniscofemoral ligaments if they are intact and if they do not hinder arthroscopic visualization. Having performed the above, an accessory posteromedial (PM) portal is established under arthroscopic visualization with a spinal needle, followed by a stab incision and blunt intra-articular dissection.

The tibial PCL footprint is identified by careful performing subperiosteal dissection using a radiofrequency ablation device and shaver placed through the PM portal while visualizing through the AL portal. A PCL tibial guide set at 60 or 65° is placed against the tibial spines and between 10 and 15 mm distal to the joint line to precisely locate the tibial footprint for tunnel drilling. A 3-cm incision is made along the AM aspect of the tibia and a guidewire is advanced into the PCL tibial guide and fluoroscopic imaging is used to confirm appropriate placement. Afterwards, a 10-mm tibial socket is reamed under direct fluoroscopic and arthroscopic visualization.

Next, the femoral tunnel is created using an outside-in technique. A 3-cm incision along the AM aspect of the distal femur is made, and dissection is carried down through the skin to the bone. A small periosteal window is made, and the femoral Anatomic ACL Guide System of the contralateral knee is used focusing that the guidewire enters the PCL intra articular femoral footprint focusing mainly on the origin of the AL bundle. After the guide has been positioned properly, a guidewire is placed in an outside-in manner with arthroscopic confirmation. A 10 mm tunnel is reamed in an

outside-in manner over the guidewire. Care should be taken to ensure that there is at least 2-mm bridge of bone between the tunnel and the anterior aspect of the femur.

A passing suture is inserted in a retrograde fashion from the tibial tunnel into the femoral tunnel and then retrieved through the AM aspect of the femur. The passing suture is then utilized to pass a previously prepared 10 mm posterior tibial allograft from the femoral tunnel into the tibial tunnel.

Once the graft is passed, the allograft is secured in the femoral tunnel with a 11 × 30 mm aperture interference BioRCI screw (Smith & Nephew, Andover, MA). Attention is then directed to final fixation of the tibial graft. With the knee flexed to 90° and a significant anterior drawer force on the proximal tibia, the graft is tensioned manually and secured in the tibial tunnel with an 11 × 30-mm BioRCI screw. At this point, excess graft was trimmed flush with the cortical surface after confirming correct screw positioning. Finally, closure of the incisions is completed through a standard layered fashion.

Double bundle transtibial PCL reconstruction

The surgery begins in the same manner as described for single bundle PCL reconstruction. The tibial tunnel is also prepared and created in the same manner, using a single 10 mm tibial tunnel. Then 2 femoral tunnels are made, replicating the origin of the AL and PM bundles. The femoral tunnel of the AL bundle is made using a guide wire in an inside-out manner.

The more anterior aspect of the AL bundle is noted by the trochlear point, and the more inferoposterior aspect is delineated by the medial arch point. With the guide wire in its correct position, a 10 mm tunnel is reamed using an inside-out technique.

Then the PM bundle tunnel is made for which we use the femoral Anatomic ACL Guide System of the contralateral knee in such a way that the guidewire enters the PM bundle intra articular femoral footprint. The PM bundle tunnel was located along the medial femoral condyle wall, distal to the medial arch point, approximately 8 to 9 mm posterior to the edge of the articular cartilage of the medial femoral condyle and slightly posterior to the AL bundle tunnel. After the guide has been positioned properly, a guidewire is placed with arthroscopic confirmation and a new femoral tunnel is made using the outside-in technique.

While the tibial and femoral tunnels are positioned and reamed by the head surgeon, an assistant prepares a 9.5–10 mm diameter posterior or anterior tibialis tendon allograft and a 6 mm semitendinosus tendon autograft on an adjacent table.

With the 2 femoral tunnels already made, the allograft is passed through the AL bundle tunnel and the ST autograft through the PM bundle tunnel from proximal to distal, with both grafts being retrieved through the tibial tunnel. Then the grafts are fixed using Biorci Smith & Nephew interference screws. We begin with the femoral fixation of the allograft in the femoral tunnel that gives rise to the AL bundle with the knee in a resting position flexed 90°.

Tibial fixation of both grafts is then performed while applying anterior translation of the tibia with the knee at 90° of flexion. Next, femoral fixation of the semitendinosus autograft is performed with the knee in full extension in an outside-in manner.

At this point, excess graft was trimmed flush with the cortical surface after confirming correct screw positioning. Finally, closure of the incisions is completed through a standard layered fashion.

Schematic view of tunnel placement for both SB and DB PCL-R techniques is presented in Fig. 1.

Postoperative rehabilitation

The foundation of the rehabilitation process focuses on strengthening the quadriceps and minimizing posterior tibial translation caused by gravity or hamstring activity.

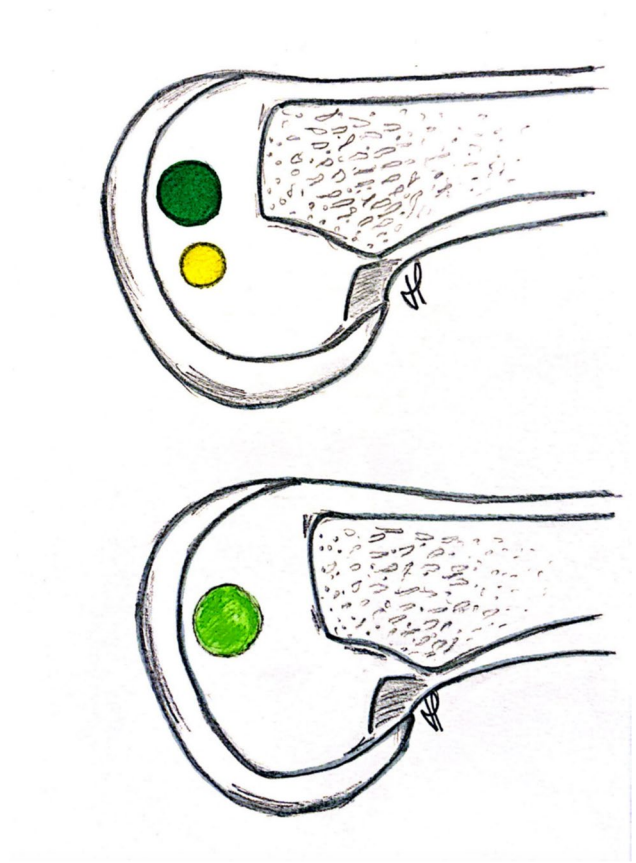


Fig. 1 Schematic lateral view of medial femoral condyle. DB tunnels (top) show AL in dark green and PM in yellow; SB tunnel (bottom) is in light green

The key aspects considered in our rehabilitation protocol include weight-bearing (WB), the use of a dynamic knee brace—M4 PCL (Medi, Bayreuth, Germany)—and range of motion (ROM), all of which are progressively adjusted throughout the rehabilitation process. Initially, non-weight-bearing is indicated with the brace locked in full extension, along with prone passive ROM exercises (0–60°), progressing to partial WB only after the fourth week. By the sixth week, WB is allowed as tolerated, and prone passive ROM is advanced to 0–120°. At week 7, the brace is unlocked to allow up to 90° of flexion, and by week 9, full ROM is permitted with the initiation of active ROM exercises in the supine position. Brace use becomes optional after completing the 12-week rehabilitation protocol.

Statistical analysis

For descriptive statistics, categorical variables were listed and ordered in frequency tables. As for continuous variables, the Shapiro-Wilks test was used, accompanied by a visual inspection of the histograms in order to determine the distribution. Due that none of the variables had a normal distribution, median and interquartile range were employed as measures of central tendency.

Due to the study's design, sample size was not determined. 2 groups were compared in the present study: patients underwent surgery with the SB technique (Group 1) and those treated with DB technique (Group 2). Chi-square test was used to frequency calculation of categorical variables. The U Mann–Whitney test was used to compare the continuous variables due the lack of a normal distribution of data.

A multivariate linear regression model was performed to evaluate potential confounding variables associated with return-to-work time. The model included surgical technique (single vs. double-bundle), graft type, and age as independent variables.

Statistical analysis was performed using STATA 18 (STATAcorp, Chicago, IL). A significance level of $p < 0.05$ (95% CI) was set to designate statistical significance.

Results

A total of 49 PCL-R were identified in our database. Twenty-seven of them were not included in the study due to our exclusion criteria, as specified in Fig. 2.

Lastly, twenty-one patients were included in our study, one of them with a bilateral PCL injury, with a total sample size of 22 PCL-R, of which 77.3% of them were male subjects (17 patients). The median of age was 30 years-old (interquartile range p25 and p75 (IQR) 25.5–35.75). 4 of them listed comorbidities (2 high blood pressure and 2 obesity) and 10 of them identified as smokers. The rest of the sample characteristics are listed in Table 1.

The median of time elapsed from PCL diagnosis to surgery was 116 days (IQR 18–196 days) and 128 days (IQR 26–201 days) for DB-PCL and SB-PCL, respectively.

Fourteen patients underwent surgery using the SB technique (63.64%) and composed the Group 1. Allograft was used in 8 knees (4 Achilles tendon, 3 tibialis posterior tendon and 1 tibialis anterior tendon), semitendinosus-gracilis autograft was used in only 1 knee, and bone-tendon-bone patellar tendon autograft was used in 5 knees. DB technique was performed in 8 subjects (36.36%), using allograft in 5 patients and autograft plus allograft in 3 patients (3 semitendinosus-gracilis autograft plus 3 tibialis posterior tendons allograft).

Both groups were comparable according to their demographic characteristics as listed in Table 1. Only obesity presented a $p = 0.050$ after Chi-square test application, although after simple logistic regression without any adjustment of the other variables the p value was 0.178, with no significant difference between groups.

We decided to evaluate the pre-injury workload of patients undergoing PCL-R. Since no specific classification of physical work intensity exists in our country, we opted to use the German "Reichsausschuss für Arbeitszeitermittlung (REFA)" classification, which includes 5 categories. Categories ≥ 2 indicate moderate, heavy, or very heavy workload. In this study, both groups were comparable in terms of work intensity prior to the accident ($p = 0.908$).

The median of total work-days lost because of the injury was 176.5 days (IQR 157–250). There were no statistical differences between both groups, with a median of 176.5 days (IQR 157–250) for the SB group and 176.5 days (IQR 130–270) for the DB group (p value 0.516).

Functional outcomes are listed in Table 2. The KOOS median for all the patients was 72.3 (IQR 59.5–90.5), with KOOS 77.7 (IQR 59.5–93.4) and 70.2 (55.95–75.3) for the SB and DB groups, respectively, with no statistically significant differences after application of U Mann–Whitney test ($p = 0.356$).

A total median of 76.39 (IQR 63.89–88.89) was obtained for the Pain subscale of KOOS, with differences between both groups, 84.72 (IQR 66.67–97.22) for SB group and 70.83 (IQR 55.55–79.16) for DB group. These differences did not reach statistical significance, with a p value of 0.149. The total median for KOOS daily life activities was 82.35 (IQR 65.75–94.12), with no statistical differences between groups (SB Group 88.24 (IQR 67.65–98.53), DB Group 80.15 (IQR 68.39–82.35), p = 0.194).

Regarding the Lysholm score, good results were obtained in both groups, with no significant differences ($p = 0.429$). The median was 90 (IQR 80–95), 92 (IQR 83–95) and 89 (69–94), for total, SB Group and DB Group, respectively.

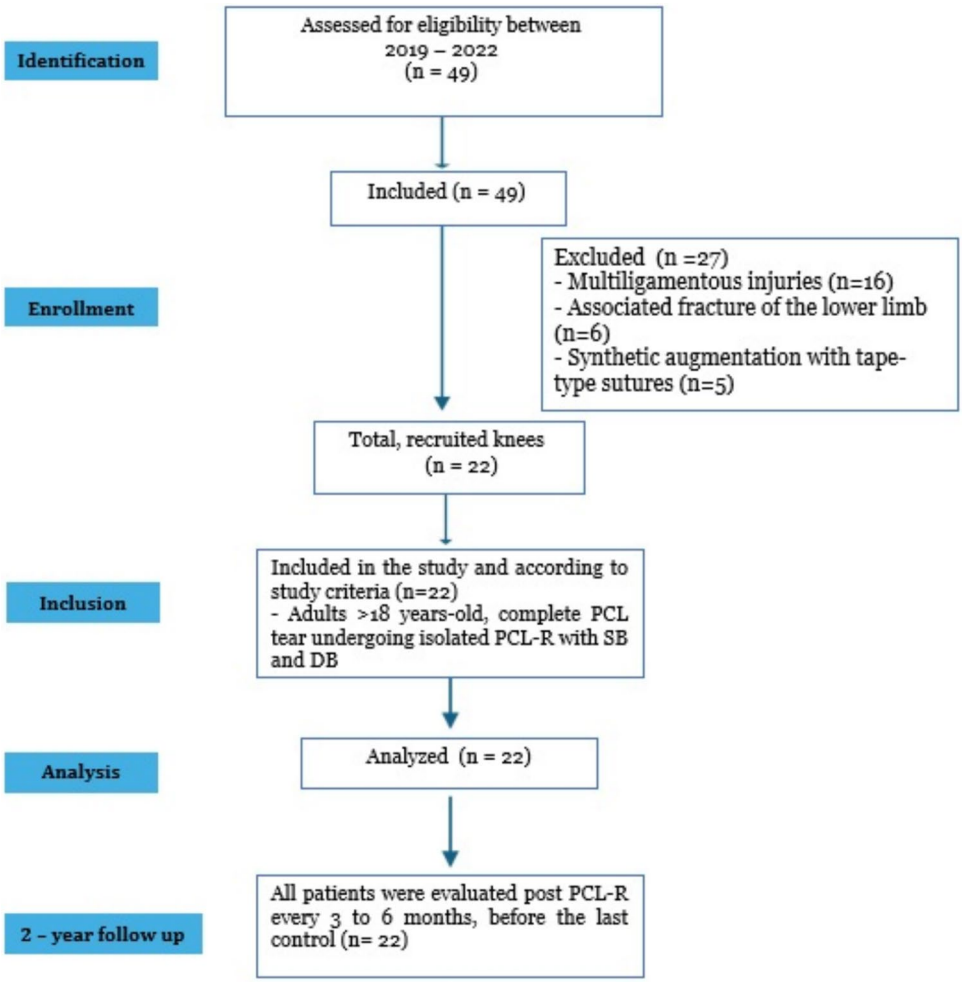


Fig. 2 STROBE-compliant flow diagram illustrating patient inclusion, exclusion criteria, and final sample analyzed. Created following the format by Rathleff et al. [33]

Table 1 Demographic characteristics

	Total $n=22$	Single-bundle $n=14$	Double-bundle $n=8$	p
Sex Male, *n* (%)	17 (77.7%)	11 (78.57%)	6 (75%)	0.848
Age (Me, IQR)	30 (25.5–35.75)	27.5 (25–31)	33.5 (31–39.5)	0.065
Medical history	2 (9.09%)	2 (14.29%)	0	0.262
HTN, *n* (%)	2 (9.09%)	0	2 (25%)	0.050
Obesity, *n* (%)	10 (45.45%)	8 (57.14%)	2 (25%)	0.145
Smoker, *n* (%)				
Laterality Right knee, *n* (%)	6 (27.27%)	5 (35.71%)	1 (12.50%)	0.240
Workload prior to the accident* (REFA ≥ 2), *n* (%)	19 (86.4%)	12 (85.7%)	7 (87.5%)	0.908

Me Median; *IQR* Interquartile range p25 and p75; *HTN* Hypertension; *REFA* Reichsausschuss für Arbeitszeitermittlung; * according the REFA classification

No significant differences were found between groups regarding range of movement (ROM) (120°, IQR 115°-120° for Group 1 vs 120°, IQR 120°-125° for Group 2, p = 0.191).

Arthrofibrosis, defined as flexion deficit > 10°, developed in 5 patients, 4 from the SB Group (28.57%) and 1 from the DB Group (12.5%), with no statistical differences between groups (p = 0.387). Of them, 3 patients required a reintervention for arthroscopic arthrolysis and mobilization under anesthesia (2 SB and 1 DB, $p=0.907$). Only one patient of the SB Group presented graft failure (4.54%). This patient was initially intervened 5 months after the injury due to failure of nonoperative treatment and then required a revision

of the PCL-R. No graft re-rupture was observed in the DB Group. All complications are listed in Table 3.

A comparative summary of clinical outcomes between SB and DB techniques is presented in Table 4. No statistically significant differences were observed in any of the analyzed variables, including return-to-work time, functional scores (KOOS and Lysholm), and complication rates.

Finally, a univariate analysis was performed to identify factors associated with the number of workdays lost. The Mann–Whitney U test was used for categorical variables. No significant associations were found between time off work and variables such as sex ($p = 0.505$), smoking status ($p = 0.070$), comorbidities ($p = 0.250$), or postoperative joint stiffness ($p = 0.080$). However, smokers had a median of 235 days off work compared to 166 days for non-smokers, indicating a trend toward longer work absence. Similarly, patients with postoperative knee stiffness had a median of 257 days off work, compared to 174 days in those without stiffness, suggesting a possible influence of joint stiffness on recovery time. Spearman correlation analysis revealed no significant relationship between age ($p = 0.070$) or the interval from injury to surgery ($p = 0.549$) and the number of workdays lost. Although no preoperative predictors of return-to-work time reached statistical significance, the observed trends may have clinical relevance and warrant further investigation in larger cohorts. In a multivariate linear regression model including surgical technique (SB vs. DB), graft type, and age showed that the DB PCL-R was associated with an average reduction of 36.6 days (95% CI: -139.9 to 66.7) in return-to-work time compared to the SB PCL-R, although this difference was not statistically significant ($p = 0.465$). Neither graft type nor age demonstrated statistically significant effects on return-to-work time; age showed a non-significant positive association with time off work (coefficient 3.86 days per year, 95% CI: -1.03 to 8.75; $p = 0.115$). This model simultaneously adjusted for these potential confounders, suggesting that none substantially

Table 2 Functional outcomes

	Total $n = 22$	Single-bundle $n = 14$	Double-bundle $n = 8$	*p (ranksum)*
PROMs (Me, IQR)	72.3 (59.5–90.5)	77.7 (59.5–93.4)	70.2 (55.95–75.3)	0.356
KOOS	76.39 (63.89–88.89)	84.72 (66.67–97.22)	70.83 (55.55–79.16)	0.149
KOOS (pain)	83.93 (64.29–92.86)	85.71(64.29–92.86)	73.22(62.5–89.29)	0.559
KOOS (sympt)	82.35(65.75–94.12)	88.24 (67.65–98.53)	80.15(68.39–82.35)	0.194
KOOS (ADLs)	47.5(30–85)	70(30–90)	42.5(30–60)	0.182
KOOS (sports)	50 (25–75)	50 (31.25–75)	50 (25–62.5)	0.917
KOOS QoL	90 (80–95)	92 (83–95)	89 (69–94)	0.429
Lysholm				
Lost Wd (Me, IQR)	176.5(157–250)	176.5 (159–250)	176.5 (130–270)	0.516
ROM flexion (Me, IQR)	120 (120–120)	120 (115–120)	120 (120–125)	0.191

Me Median; *IQR* Interquartile range p25-p75; *PROMs* Patient-reported outcome measures; *Lost Wd* Lost workdays; *KOOS* Knee injury and osteoarthritis score; *QoL* Quality of ilfe, *ADLs* Activities of daily living; *ROM* Range of motion

Table 3 Complications

	Total $n = 22$	Single-bundle $n = 14$	Double-bundle $n = 8$	*p*
Joint stiffness, *n* (%)	5 (22.73%)	4 (28.57%)	1 (12.50%)	0.387
Graft failure, *n* (%)	1 (4.54%)	1 (7.14%)	0	0.439
Reinterventions	3 (13.63%)	2 (14.29%)	1 (12.5%)	0.907
Fibroarthrolysis, *n* (%)	1 (4.54%)	1 (7.14%)	0	0.439
PCL revision, *n* (%)				

PCL Posterior cruciate ligament

Table 4 Summary comparison of outcomes between SB and Db PCL reconstruction

Outcome	Single-bundle ($n = 14$)	Double-bundle ($n = 8$)	*p*-value
Return-to-work time (median)	176.5 days (IQR 157–250)	176.5 days (IQR 130–270)	0.516
KOOS total (median)	77.7 (IQR 59.5–93.4)	70.2 (IQR 55.95–75.3)	0.356
Lysholm score (median)	92 (IQR 83–95)	89 (IQR 69–94)	0.429

PCL Posterior cruciate ligament, *SB* Single-bundle, *DB* Double-bundle; *IQR* Interquartile range p25-p75; *KOOS* Knee injury and osteoarthritis score

influenced the association between surgical technique and return-to-work time.

Discussion

The most significant finding of this study is that we did not observe significant differences in return-to-work times among patients with workers' compensation who underwent isolated PCL-R. Secondly, functional outcomes measured using the Lysholm and KOOS scores did not significantly differ between the 2 surgical techniques in this specific group of patients. And additionally, we found no significant differences in postoperative complications between SB and DB PCL-R.

Although several biomechanical studies agree that DB PCL-R more effectively restores the stability attributed to the PCL across the knee's range of motion [22, 34–37], clinical outcomes reveal mixed evidence regarding the superiority of DB PCL-R. Some studies report no significant differences between the 2 techniques [11, 20, 24, 27, 38, 39], while others demonstrate certain advantages of DB PCL-R over SB PCL-R in specific clinical aspects [25, 27, 35]. Our clinical findings align with the first assertion, namely that we did not identify clinical differences between the 2 techniques.

Regarding our primary outcome, namely the time to return to work following surgery, both techniques yielded comparable results, with all patients successfully resuming work. The median return-to-work time may reflect the high physical demands of the study population and the structured rehabilitation protocol. Similarly, complications may have been influenced by graft type, obesity, or surgical timing. To the best of our knowledge, no studies have evaluated the return to work in patients undergoing isolated PCL-R comparing both techniques. In this context, the limited evidence available focuses on patients reconstructed using the SB technique. In their study on the occupational consequences of patients undergoing isolated SB PCL-R with hamstring tendons, Ihle et al. [40] reported an average recovery time of 24 weeks (168 days) for patients with jobs requiring moderate to heavy physical labor, which aligns with our findings. In our case, the predominant group consisted of patients with these occupational characteristics. Conversely, Pizza et al. [41] observed a 95% return-to-work rate among patients undergoing PCL-R in their series, which included cases of combined PCL and posteromedial corner injuries.

Regarding complications associated with both techniques, the available evidence is also limited. In their comparative study of the two techniques, Jain et al. [42] reported four patients with residual laxity in the SB group, but only one patient underwent revision surgery. Additionally, 2 knees exhibited flexion less than 90 degrees, requiring manipulation under general anesthesia at 12 weeks. On the other hand, Yoon et al. [24] noted that four patients underwent additional surgeries: one in the SB group and three in the DB group. In our series, we observed 3 patients requiring reintervention due to knee stiffness (2 in the SB group and 1 in the DB group) and 1 patient requiring reintervention due to reconstruction failure in the SB group. In both cases, the differences were not statistically significant.

Interestingly, a trend toward better KOOS pain scores was observed in the SB group, and no graft failures occurred in the DB group. While these findings did not reach statistical significance, they may reflect relevant clinical tendencies that deserve further investigation. The influence of graft type variability and surgeon-driven decision-making on outcomes must also be acknowledged as potential confounding factors. Furthermore, aspects such as surgical time, technical difficulty, and cost-effectiveness of each technique were not assessed in this study but are important for real-world decision-making, particularly in high-demand or resource-limited settings. DB techniques may be associated with longer operative times and increased technical and resource demands, which could influence surgical planning in occupational populations.

Limitations

Ours is a retrospective study focusing on return-to-work and clinical outcomes in patients undergoing isolated PCL-R. In this context, the study has several limitations that may affect the generalizability of its findings. First, the small sample size, which is attributable to the rarity of isolated PCL injuries [1, 3, 4], many of which are amenable to nonoperative management, making it challenging to include a larger cohort of patients. Due to the non-normal distribution of the variables and the use of non-parametric statistical tests, a post-hoc power analysis was not conducted. This decision carries the risk of a Type II error due to the small sample size. Indeed, some of the results might have reached statistical significance with a larger cohort. Additionally, the small number of observations and the group imbalance limited the ability to reliably estimate effect sizes, such as median differences with confidence intervals. Although bootstrap methods were attempted, the resulting estimates proved unstable and were therefore not reported to avoid potentially misleading interpretations. Second, the short follow-up period, which does not allow for the assessment of long-term outcomes and complications, such as the development of osteoarthritis, graft failure, or reinterventions for associated injuries. Third, given its retrospective nature, there was no randomization of the groups, and the choice of surgical technique was determined by the operating surgeon, introducing bias in the interpretation of the results. Additionally, the time elapsed from injury to surgery was not evaluated, which could also

have influenced the outcomes. Lastly, although the surgical technique was standardized, the type of graft used varied between groups, limiting direct comparisons with similar studies. The use of different graft types across groups introduced a degree of treatment heterogeneity, which may have influenced clinical outcomes independently of the surgical technique and acted as a potential confounding factor. While this limits the internal validity of the study and the ability to isolate the effect of the reconstruction approach, it also reflects it also reflects common clinical settings and enhances the external validity of our findings by encompassing a broader range of treatment scenarios. Moreover, the lack of standardized postoperative imaging (e.g., stress radiographs or MRI) prevented objective assessment of graft healing or joint stability. These limitations, combined with the surgeon-dependent technique allocation, further reduce the ability to establish causal relationships and may influence the external validity of our findings. In this context, a future prospective, randomized study with a larger patient cohort, standardized surgical technique and graft type, and longer follow-up periods would be desirable to strengthen our findings.

Clinical relevance

Based on the findings of this study, our current approach to the surgical management of isolated PCL injuries in workers' compensation patients remains unchanged. Both SB and DB PCL-R appear to be viable surgical options, with comparable short-term outcomes in terms of return-to-work time, function, and complications. Although DB techniques may offer theoretical biomechanical advantages, our results suggest that factors such as surgical complexity, graft variability, surgeon experience, patient-specific characteristics, and resource availability may play a greater role in real-world outcomes. These insights support a flexible, patient-centered approach to surgical planning and may inform clinical decision-making, patient counseling, and resource allocation in occupational injury settings where timely functional recovery is essential.

Conclusions

SB and DB isolated PCL-R yield comparable return-to-work times, functional outcomes, and complication rates in workers' compensation patients, though results should be interpreted with caution due to study limitations. Despite biomechanical studies favoring DB reconstruction for better knee stability, clinical results remain inconclusive. Our findings align with previous studies reporting similar functional recovery between techniques. The median return-to-work time was 176.5 days, with all patients successfully resuming work. Although no statistically significant, multivariate analysis showed a trend toward reduced time to return to work in the DB group (− 36.6 days), which may suggest potential clinical relevance, especially in a larger cohort.

Given its lower technical complexity and comparable outcomes, SB reconstruction may be a reasonable first-line option in selected cases. Future prospective, randomized trials with standardized surgical techniques, uniform graft types, and longer follow-up periods are needed to validate these preliminary observations and better understand the long-term clinical implications of each technique.

Competing interests

The authors declare no competing interests.

Author Contribution We declare that all authors have seen and agreed to the submitted version of the article, and are responsible for it, and that all authors have participated in authorship and the article has not been submitted to any other journal. RO designed the study, coordinated the team, participated in data collection, abstract writing, manuscript drafting, bibliographic references, and is the corresponding author. MK and JTM were responsible for data collection, synthesis and writing of methods and results, tables, and statistical analysis. TR participated in data collection, figures, and development for approval by the ethics committee of our institution. JU, JL, and NG participated in data collection. NF worked on abstract writing and discussion.

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