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Double-bundle posterior cruciate ligament reconstruction: No differences between two types of autografts in isolated or combined lesions

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ABSTRACT

Background: To demonstrate and compare results obtained with the transtibial double-bundle posterior cruciate ligament (PCL) reconstruction technique using two types of autografts in isolated and combined PCL lesions.
Methods: Fifty-two patients with isolated or combined PCL injuries underwent double-bundle PCL reconstruction and were retrospectively evaluated. Among them, 34 were reconstructed using ipsilateral quadriceps and semitendinosus tendon grafts, and 18 were reconstructed using bilateral hamstring tendon grafts. The criteria for outcome evaluation were: objective International Knee Documentation Committee (IKDC) score, Lysholm score, posterior stability (posterior drawer test and KT-1000TM), and rate of complications, comparing the two types of grafts and comparing isolated PCL and combined lesions. The minimum follow-up was two years.
Results: Significant improvements were found in all evaluation methods between the pre- and postoperative periods (all $P < .05$), with no observed differences between the graft type that was used (all $P > .05$). The whole sample had the following results: objective IKDC score, 96.2% classified as A/B; Lysholm score, 98.1% rated as good or excellent; and KT-1000, 98.1% with a side-to-side difference of up to five millimeters (65.4% with 0 to two millimeters). The complication rate was 9.6%, with no differences between the graft type that was used ($P = .585$). No significant difference was observed when comparing the results between isolated PCL injuries and combined injuries (all $P > .05$).
Conclusions: The proposed PCL reconstruction technique presented satisfactory results in both isolated and combined PCL lesions, and there were no differences between different types of autografts used.
Level of evidence: Level III.

1. Introduction

The posterior cruciate ligament (PCL) is the primary restrictor of the posterior translation of the tibia under the femur [1]. Classically, it is divided into two functional bundles: the anterolateral (AL) bundle, which is larger and most tense in flexion, and the posteromedial (PM) bundle, which is smaller and most tense in extension [2,3]. However, this division is considered by many as an exaggerated and inaccurate simplification of a complex structure [4,5].

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Despite advances in surgical techniques, the results of PCL reconstruction do not show the same success rate when compared with anterior cruciate ligament (ACL) reconstruction, which, together with the infrequency of this injury, have led to controversies such as the number of bundles to be reconstructed, positioning of the bone tunnels, graft type used, fixation method, and surgical access routes (transtibial vs. inlay) [1,6,7].

Double-bundle reconstruction was introduced in an attempt to improve the surgical treatment results, since there is significant residual posterior laxity in many cases of single-bundle reconstruction [1,8]. The superiority of one technique over another has not yet been definitively established, although superiority of the double-bundle technique was observed in the objective evaluation of posterior stability in a recent systematic review [9], which is a finding already observed in several biomechanical studies [10–14].

Regarding the type of graft, the literature considers allografts to be the standard for multiple ligament injuries because of the required number and size of the grafts, shorter surgical time, and lower morbidity of the procedure. However, allografts also have the potential risk of disease transmission, longer integration time, potential changes in structural integrity, high cost, and limited availability [15,16]. In many countries, most services do not have access to a tissue bank, which makes autografts the only available option. When considering the use of autologous grafts in PCL reconstruction, whether it is isolated or associated with other ligamentous lesions, the current literature is very limited, and few studies have compared different autografts using the single-bundle reconstruction technique [17,18]. Furthermore, there are no studies that consider such comparison regarding double-bundle reconstruction. Thus, the purpose of the present study was to demonstrate the results of double-bundle PCL reconstruction and then to compare two types of autografts: ipsilateral quadriceps tendon and semitendinosus in one group and bilateral hamstrings in another group. It was hypothesized that the double-bundle PCL reconstruction technique using autografts is effective and that bilateral hamstrings provide similar or even higher stability with lower morbidity and fewer complications.

2. Methods

From April 2002 to February 2015, 172 patients with PCL injuries (isolated or associated with other ligamentous injuries) underwent surgical treatment at the current institution. Of these, 128 presented intrasubstance injuries and were subjected to

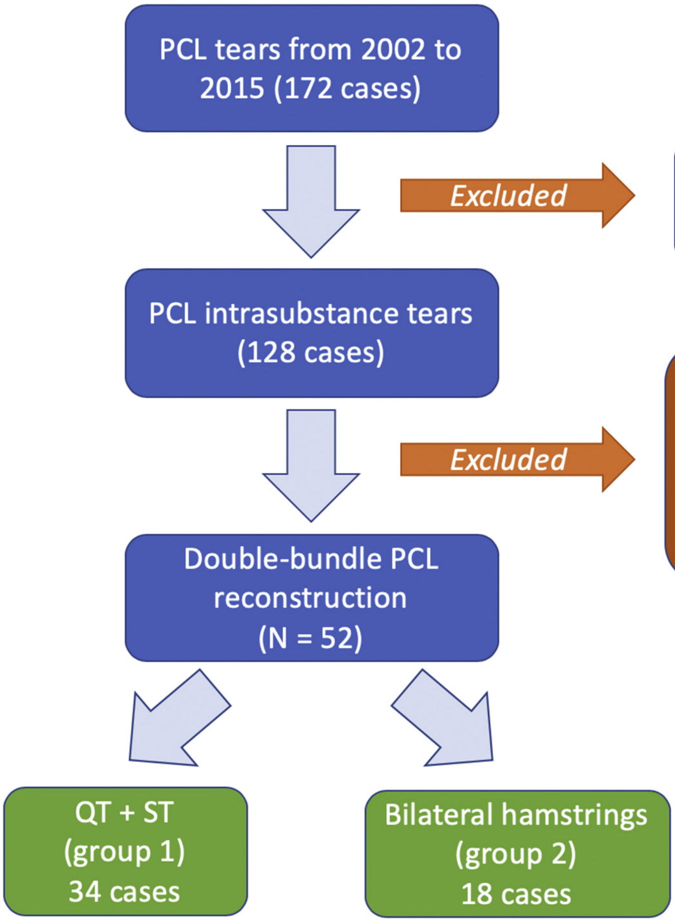

Figure 1. Diagram of all posterior cruciate ligament injuries treated in the determined time period, showing the number of cases included and excluded in the present study. PCL, posterior cruciate ligament; QT, quadriceps tendon; ST, semitendinosus tendon.

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arthroscopic PCL reconstruction. Hence, the present study involved a cohort of consecutive cases and included all patients who underwent double-bundle PCL reconstruction during the aforementioned period (Figure 1). The research protocol was approved by the institutional Research Ethics Committee.

As inclusion criteria, patients were considered who were skeletally mature, of any age, and presenting with intrasubstance isolated grade III injuries or combined PCL lesions. The subjects all had a stable contralateral knee and no history of previous injuries or surgeries on either knee; they had a minimum postoperative follow-up of 24 months, regardless of the time period from injury to surgery. As non-inclusion criteria, patients were considered with radiographic signs of osteoarthrosis (Kellgren-Lawrence grade I or above), associated bone injuries in the affected knee, a history of contralateral knee injuries, and with grade I and II isolated PCL injuries. Furthermore, patients were excluded who did not adequately perform the postoperative rehabilitation according to the published protocol or who were unable to undergo outpatient follow-up for at least two years [19].

After applying the aforementioned criteria, 52 patients were included (Figure 1). In 34 patients, treated from 2002 to 2011, the grafts used were the quadriceps tendon combined with semitendinosus tendon harvested from the ipsilateral knee (QT + ST — group 1); in 18 patients, treated from 2011 to 2015, the grafts used were the tendons of the graciles and semitendinosi muscles harvested from both knees (flexor tendons — group 2). Thirty-one patients had associated ligament injuries (59.6%), and 21 had isolated PCL injuries (40.4%). Among the patients with associated injuries, 10 presented injuries of the posterolateral corner structures (PLC — 32.3%), 10 presented ACL injuries (32.3%), seven had PCL and ACL injuries (22.6%), and four had an associated injury of the posteromedial corner (PMC — 12.9%).

2.1. Diagnosis

A detailed physical examination was performed by two authors, both experienced orthopedic surgeons, to diagnose the ligamentous injuries. The tests performed were: anterior and posterior drawers (at neutral, internal and external rotations); Lachman's; Godfrey's; valgus/varus stress (at 30° and full extension); Dial; pivot-shift; reverse pivot-shift; and external rotation-recurvatum [20]. The PCL injury grade was determined by the posterior drawer (PD) test performed in neutral rotation (grade I, II or III). In total, nine patients presented PD classified as grade II (eight in group 1, and one in group 2), and 43 were classified as grade III (26 in group 1, and 17 in group 2). All patients were symptomatic with gross instability and/or anterior knee pain.

The pre-operative radiological evaluation consisted of anteroposterior, lateral, and axial radiographic views of both knees, along with a panoramic standing anteroposterior radiographic view of the lower limbs. All radiographs were repeated on the affected knee after surgery, except for the panoramic view. No patient presented with an indication of lower limb axis correction. Magnetic resonance imaging was performed before surgery in all patients to assist in the diagnosis of concomitant ligamentous, chondral, and meniscal lesions.

2.2. Outcome evaluation methods

To evaluate the outcome, the following criteria were considered and applied in the pre-operative period and two years after surgery:

2.2.1. Primary outcomes

1. International Knee Documentation Committee (IKDC) objective form.
2. Lysholm questionnaire.

2.2.2. Secondary outcomes

1. PD test.
2. KT-1000™ arthrometer evaluation.

Two authors administered the PD test and KT-1000™ evaluation (side-to-side difference).

2.2.3. Complications

The occurrence of joint stiffness, infection, morbidity in the area of graft harvesting, need for a new surgical procedure (manipulation, treatment of other injuries), ligament re-rupture rate, and significant loss of muscle strength were evaluated. Joint stiffness was defined as failure to achieve at least 90° knee flexion at eight weeks postoperatively, which required surgical manipulation.

2.3. Surgical technique

All patients underwent surgical treatment by the same author, who was one of the two surgeons who diagnosed the ligamentous lesions. In group 1, quadriceps tendon grafts were used to reproduce the AL bundle, and semitendinosus tendon grafts were used to reproduce the PM bundle; both were harvested from the ipsilateral knee. In group 2, two semitendinosi tendon grafts were used to reproduce the AL bundle, and two gracile tendon grafts were used to reproduce the PM bundle, which were harvested from both knees. The surgical procedure for reconstruction of the PCL is summed up in Figure 2.

After physical examination under sedation, the grafts were harvested. The hamstrings were removed with the aid of a tenotome and folded in half (doubled). The central third of the quadriceps tendon, which was 10-cm long and one-centimeter wide and associated with a two-centimeter long patellar bone block (one centimeter thick and one centimeter wide) was removed with care not to damage the articular cartilage of the patella. All grafts were prepared with strong suture threads at their ends (Ethibond™ n. 2, Vicryl™ n. 1).

After arthroscopic articular inspection and treatment of any meniscal and chondral injuries, the injured ligament was debrided. An arthroscopic posteromedial accessory portal was used in every case. The tibial tunnel was first prepared with the aid of fluoroscopy for proper positioning of the guidewire (Figure 3). The femoral tunnels were prepared in an outside-in manner. The tunnel corresponding to the AL bundle was positioned at a distance of seven millimeters from the edge of the anterior cartilage of the medial femoral condyle, in the 00:30 clock position in the right knee and the 11:30 clock position in the left knee. The tunnel corresponding to the PM bundle was made posteriorly to the AL tunnel at a distance of nine millimeters from the anterior cartilage edge at approximately three (right knee) or nine o'clock (left knee)(Figure 4).

Due to the presence of the bone block and short length of the quadriceps tendon graft, the graft fixation differed between groups. In group 1, with the bone block portion of the quadriceps graft left in the AL tunnel, fixation of both grafts was initially performed in the femur with metal interference screws. Next, the grafts were fixed to the tibia with cortical screws and washers, performing a 'pole' fixation independently for each bundle. The AL graft was fixed in 90° flexion, and the PM graft was fixed in full extension (Figure 5a). In group 2, tibial fixation was first performed with a single metal interference screw for both bundles, followed by femoral fixation at the same angles of flexion described for AL and PM bundles; this fixation was also performed with metal interference screws (Figure 5b).

When an associated ACL injury was present, the reconstruction was performed using the central third of the patellar ligament, which was removed from the contralateral knee in group 1 and from the ipsilateral knee in group 2. In cases of an associated PLC injury, the technique recommended by Fanelli et al. was performed using a contralateral semitendinosus graft in group 1 [21]. In group 2, the grafts were changed to one semitendinosus plus one gracilis graft for the AL bundle and one gracilis graft for the PM bundle, with the remaining semitendinosus used for reconstruction of the PLC using the same technique [21]. In cases of PMC injury, reconstruction was similarly performed using one semitendinosus graft and fixed at the femoral and tibial anatomical insertion points of the medial collateral ligament with screws and spiked washers.

2.4. Rehabilitation

The rehabilitation protocol was standardized at the institution and there were no differences in the protocol regarding graft type [19]. In cases of isolated injuries, partial weightbearing was initiated in the first two weeks with the aid of crutches and a knee immobilizer in extension for six weeks combined with immediate onset of passive joint amplitude gain. In cases where the PLC or PMC was also reconstructed, the same procedure was followed, except patients remained non-weightbearing during the immobilization period.

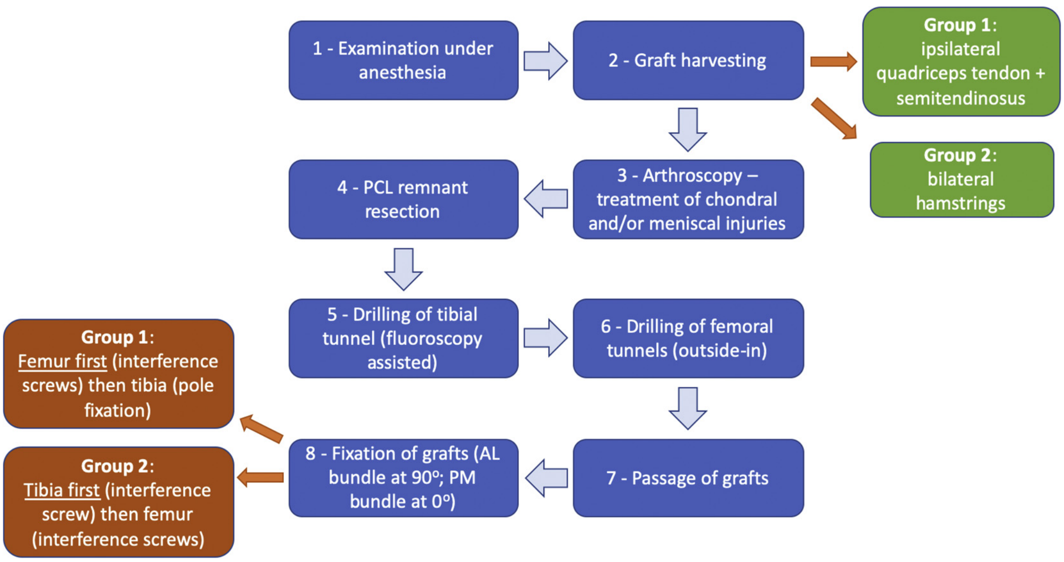

Figure 2. Diagram summing up the surgical technique used for double-bundle posterior cruciate ligament reconstruction, highlighting the differences between groups 1 and 2. PCL, posterior cruciate ligament; AL, anterolateral; PM, posteromedial.

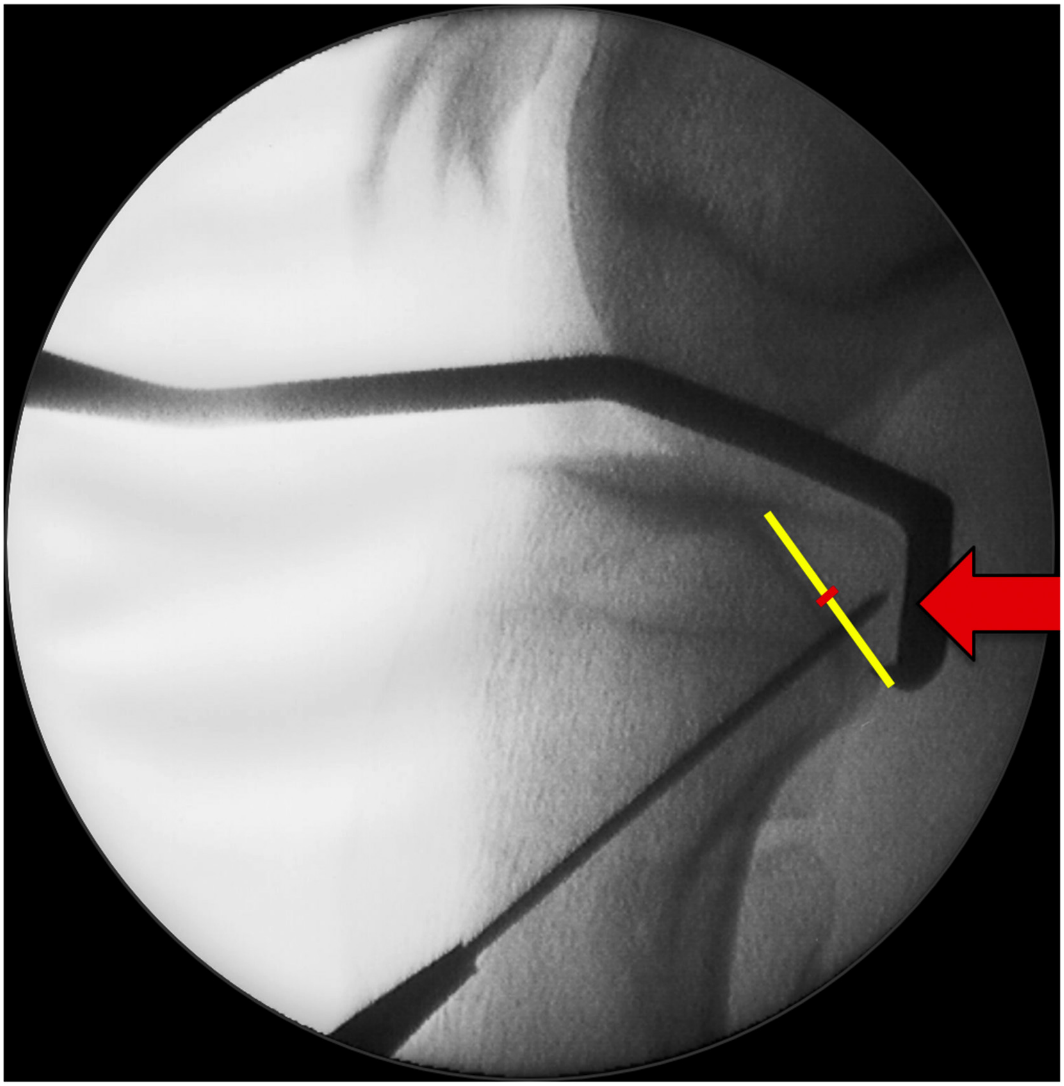

Figure 3. Location of guidewire positioning for creating the tibial tunnel - center of the lower half of the PCL insertion facet. (The yellow line shows the PCL insertion facet, with the red detail marking its center. The red arrow shows the adequate position of the guide pin for creating the tibial tunnel (center of the lower half of the PCL insertion facet)).

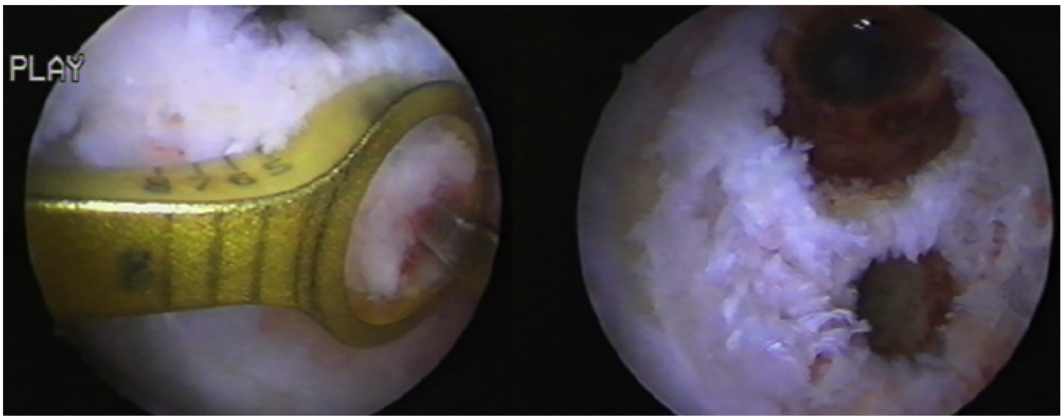

Figure 4. Preparation of the outside-in femoral tunnels.

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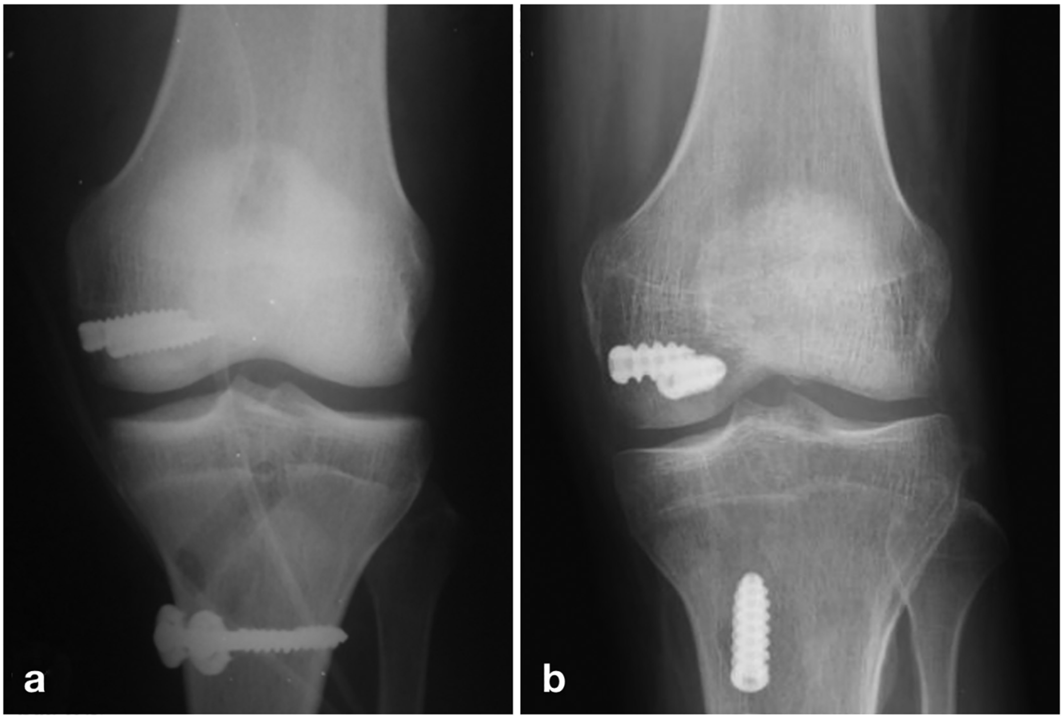

Figure 5. Radiographic appearance: position of the screws after PCL reconstruction (a. group 1; b. group 2).

2.5. Statistical analysis

Patient ages were described with summary measures and compared with Student's *t*-test [22]. A Chi-square or exact test was used for qualitative characteristics [22]. The results of the questionnaires and outcome evaluation tests were described according to graft type and time of evaluation using absolute and relative frequencies and compared with the use of generalized estimating equations with marginal Poisson distribution and identity link function [23]. The analyses were followed by Bonferroni multiple comparisons [24]. The level of statistical significance was set at five percent ($P \leq .05$).

3. Results

The various epidemiological variables were statistically compared between the groups. None of the analyzed variables significantly differed between the groups, except for the presence of associated meniscal and/or chondral injuries, which were more frequently found in group 1 (Table 1).

3.1. General analysis of the sample

The results were compared between the pre-operative and postoperative periods with two years of follow-up. When comparing the pre-operative and postoperative evaluations, there was an expressive and statistically significant improvement in all variables. Additionally, no significant difference was observed between the results when comparing the two groups (Table 2).

Considering the whole sample, a mean postoperative Lysholm score of 92.94 was observed, with 98.1% classified as excellent or good; for the IKDC score, 96.1% were classified as A or B; and with the KT-1000 side-to-side difference and posterior drawer test, 98.1% had a negligible difference (0 to two millimeters or negative) or a minimum difference (up to five millimeters or positive +/3). The results of each evaluation method are shown in Table 2.

3.1.1. Complications

Five patients (9.6%) experienced complications. There was no significant difference between the groups ($P = .585$). The most common complication was joint stiffness, with three cases in group 1 (two patients with an isolated injury, and one with a combined PCL + ACL + PLC injury – 8.8%) and one case in group 2 (combined PCL + PLC injury – 5.6%); all of the injury cases presented a flexion deficit, as previously stated. In these cases, intervention was required for arthroscopic debridement and manipulation under anesthesia eight weeks after surgery, after which all of them progressed satisfactorily. One patient in group 1 (isolated injury) developed serious postoperative pain five months after surgery; a medial meniscal injury was detected and resolved with partial resection. No significant loss of muscle strength, postoperative infection, deep venous thrombosis/pulmonary

Table 1
Personal and clinical characteristics of the sample according to graft type and statistical test results.

Variable	Type of graft used		Total (N = 52)	*P*
	Group 1 (N = 34)	Group 2 (N = 18)		
Age (years)				0.557[b]
Mean ± SD	31.3 ± 6.7	30 ± 8.5	30.8 ± 7.3	
Sex, n (%)				0.399[a]
Male	28 (82.4)	17 (94.4)	45 (86.5)	
Female	6 (17.6)	1 (5.6)	7 (13.5)	
Laterality, n (%)				0.335
Right	16 (47.1)	11 (61.1)	27 (51.9)	
Left	18 (52.9)	7 (38.9)	25 (48.1)	
Type of trauma, n (%)				0.205[c]
Motorcycle	18 (52.9)	11 (61.1)	29 (55.8)	
Car	5 (14.7)	0 (0)	5 (9.6)	
Sport	9 (26.5)	6 (33.3)	15 (28.8)	
Other	2 (5.9)	1 (5.6)	3 (5.8)	
Diagnosis of injury, n (%)				0.602[a]
Acute	2 (5.9)	2 (11.1)	4 (7.7)	
Chronic	32 (94.1)	16 (88.9)	48 (92.3)	
Associated injury, n (%)				0.058[c]
No	14 (41.2)	7 (38.9)	21 (40.4)	
PCL + ACL	7 (20.6)	3 (16.7)	10 (19.2)	
PCL + ACL + PLC	7 (20.6)	0 (0)	7 (13.5)	
PCL + PLC	4 (11.8)	6 (33.3)	10 (19.2)	
PCL + PMC	2 (5.9)	2 (11.1)	4 (7.7)	
Chondral/meniscal injury, n (%)				**0.006**[c]
No	13 (38.2)	15 (83.3)	28 (53.8)	
Meniscal	9 (26.5)	1 (5.6)	10 (19.2)	
Chondral	5 (14.7)	0 (0)	5 (9.6)	
Both	7 (20.6)	2 (11.1)	9 (17.3)	
Complications, n (%)				0.585[c]
None	30 (88.2)	17 (94.4)	47 (90.4)	
Stiffness	3 (8.8)	1 (5.6)	4 (7.7)	
Other	1 (2.9)	0 (0)	1 (1.9)	
Need for second surgery, n (%)				0.585[c]
No	30 (88.2)	17 (94.4)	47 (90.4)	
Manipulation	3 (8.8)	1 (5.6)	4 (7.7)	
Other	1 (2.9)	0 (0)	1 (1.9)	

Chi-square test.
[a] Fisher's exact test.
[b] Student's *t*-test.
[c] Likelihood ratio test.

embolism, ligament re-rupture, or persistence of significant symptoms were observed in the area of graft harvest after two years of follow-up.

3.2. Subgroup analysis

After global analysis of the sample, groups 1 and 2 were subdivided into isolated and combined injuries, and a new statistical comparison was performed. Again, no differences were observed between the subgroups. Therefore, graft type did not significantly influence the results, regardless of whether the injury was isolated or combined (Table 3).

4. Discussion

The present study is the continuation of research that began several years ago and represents the results of decades of experience in PCL injury treatment [25–27]. With the double-bundle reconstruction technique using autografts, a statistically significant improvement was observed in all parameters used to evaluate the outcome, regardless of the type of graft used or the presence of associated ligament injuries. Therefore, these findings are generally consistent or even superior compared with the available literature [18,28–31]. Considering the total number of patients, a mean postoperative Lysholm score of 92.94 was observed, with 98.1% classified as excellent or good; in the objective IKDC score, 96.1% were classified as A or B; and in the KT-1000 side-to-side difference, 98.1% had a negligible difference (0 to two millimeters) or a minimum difference (up to 5 mm). In a study with a similar design, Jain et al. observed a slight superiority in objective criteria for double-bundle over single-bundle reconstruction, showing a mean postoperative Lysholm score of 84.22; in the IKDC score, 88.9% of the cases were classified as A or B; and a mean difference of 1.78 mm in the KT-1000 side-to-side evaluation was observed in the group where double-bundle reconstruction was performed [30]. In a case series using autologous patellar and semitendinosus tendon grafts, Garofalo

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Table 2
Comparison of the Lysholm score, IKDC grade and KT-1000 evaluation and posterior drawer test results according to graft type and evaluation times for all patients. Bold: statistically significant comparison (value of p < 0,05).

Variable	Group 1 (N = 34)		Group 2 (N = 18)		Pre-operative and postoperative comparison (*P*)	Intragroup comparison (*P*)
	Pre-operative	Postoperative	Pre-operative	Postoperative		
Lysholm (mean score)	51.82	92.94	53.55	94.16		
Lysholm (%)					<**0.001**	0.899
Excellent	0 (0)	15 (44.1)	0 (0)	11 (61.1)		
Good	2 (5.9)	19 (55.9)	3 (16.7)	6 (33.3)		
Regular	12 (35.3)	0 (0)	2 (11.1)	1 (5.6)		
Poor	20 (58.8)	0 (0)	13 (72.2)	0 (0)		
IKDC (%)					<**0.001**	0.479
A	0 (0)	4 (11.8)	0 (0)	6 (33.3)		
B	0 (0)	28 (82.4)	0 (0)	12 (66.7)		
C	6 (17.6)	2 (5.9)	6 (33.3)	0 (0)		
D	28 (82.4)	0 (0)	12 (66.7)	0 (0)		
KT-1000 (%)					<**0.001**	0.9
0 to 2	0 (0)	20 (58.8)	0 (0)	14 (77.8)		
3 to 5	0 (0)	13 (38.2)	0 (0)	4 (22.2)		
6 to 10	9 (26.5)	1 (2.9)	2 (11.1)	0 (0)		
> 10	25 (73.5)	0 (0)	16 (88.9)	0 (0)		
Posterior drawer (%)					<**0.001**	0.852
Negative	0 (0)	20 (58.8)	0 (0)	15 (83.3)		
+	0 (0)	13 (38.2)	0 (0)	3 (16.7)		
++	8 (23.5)	1 (2.9)	1 (5.6)	0 (0)		
+++	26 (76.5)	0 (0)	17 (94.4)	0 (0)		

et al. also demonstrated the effectiveness of double-bundle reconstruction, reporting a mean postoperative Lysholm score of 87.5 and 61% of results classified as A or B on the IKDC score [29]. In turn, Chan et al. reported a mean postoperative Lysholm score of 93, with 90% classified as excellent or good and 85% classified as A or B on the IKDC score in a series evaluating the effectiveness of single-bundle PCL reconstruction using autologous flexor tendons [28]. In a study comparing the use of four-strand versus seven-strand flexor tendons but performing single-bundle reconstruction, Zhao et al. reported mean postoperative Lysholm scores of 83 or 92, IKDC scores classified as A or B in 76.2% or 90.9% of cases, and a KT-1000 side-to-side difference of up to five millimeters in 80.95% or 95.45%, respectively [31]. In a case series comparing the use of flexor tendons with quadriceps tendons in single-bundle reconstruction, Chen et al. reported 89% and 86% excellent or good results for the Lysholm score; 81% and 82% A or B results for the IKDC score; and 56% and 59% of cases presenting a KT-1000 side-to-side difference of three to five millimeters, respectively [18]. Finally, when comparing the results of the present series and the others that are cited, results that are superior to those presented by Kim et al. were observed [8], in a systematic review on single-bundle reconstruction, which showed that 75% of patients were objectively classified as normal or almost normal in the IKDC objective score, while the current study obtained 96.1% as normal or almost normal across the total sample.

In general, the literature prioritizes the use of allografts, which enable faster surgical procedure and lower morbidity. However, the availability of homologous tissues is limited in the current setting, often leaving autografts as the only option. Despite the preference, there is no evidence demonstrating the superiority of allografts versus autografts. In systematic reviews with meta-analyses, Belk et al. and Tian et al. concluded that both graft types are effective, but autografts are slightly superior in the correction of anteroposterior laxity and on the Tegner scale [32,33]. If the comparison between the two graft types in primary ACL reconstruction are considered, an injury with more robust literature, two recent systematic reviews demonstrated no significant differences, except in the comparison between irradiated autografts and allografts, favoring the former [34,35]. A finding that draws attention in the review conducted by Wang et al. is the failure rate reported in two studies: two percent in patients undergoing reconstruction with an autograft compared with four percent in patients with an irradiated allograft [34]. Although it is not possible to directly extrapolate these results to PCL reconstruction, there is no reason to believe that allografts present significantly different results in the reconstruction of this ligament, especially considering the greater mechanical stress to which the PCL is naturally submitted.

One of the objectives of this series was to compare two types of autografts for double-bundle PCL reconstruction; no other previous study has made such a comparison. The quadriceps tendon associated with the semitendinosus tendon was the initial graft choice; however, as treatment experience of these complex cases grew, modification of the graft type occurred. This was based on two assumptions: first, the use of bilateral flexor tendons would lead to lower postoperative morbidity since there would be no aggression to the extensor apparatus; and second, the subsequent stability would be improved since when changing the graft type, the type of fixation would also change. Fixation with interference screws would be more reliable and stable as only the 'screw-graft-bone' interface is present. In contrast, with 'pole' fixation, the 'tendon-suture' and 'suture-screw/washer' interfaces are present and, in theory, more prone to premature mechanical failure. However, despite these theoretical advantages, significantly statistical superiority of the bilateral hamstrings was not observed, and both groups had comparable results including complication rates. The available literature comparing different autografts in PCL reconstruction is very scarce. Only two studies on this specific subject were found. Chen

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Table 3
Statistical analysis of the Lysholm score, IKDC grade, KT-1000 evaluation and posterior drawer test results according to graft type and time of evaluation for isolated and combined injuries subgroups. Bold: statistically significant comparison (value of p < 0,05).

Isolated injuries Variable	Group 1 (N = 14)		Group 2 (N = 7)		Pre-operative and postoperative comparison (*P*)	Intragroup comparison (*P*)
	Pre-operative	Postoperative	Pre-operative	Postoperative		
Lysholm (mean score)	64.5	93.5	61.42	94.14		
Lysholm (%)					<**0.001**	0.953
Excellent	0 (0)	8 (57.1)	0 (0)	4 (57.1)		
Good	1 (7.1)	6 (42.9)	3 (42.9)	3 (42.9)		
Regular	9 (64.3)	0 (0)	0 (0)	0 (0)		
Poor	4 (28.6)	0 (0)	4 (57.1)	0 (0)		
IKDC (%)					**0.002**	0.739
A	0 (0)	3 (21.4)	0 (0)	1 (14.3)		
B	0 (0)	10 (71.4)	0 (0)	6 (85.7)		
C	4 (28.6)	1 (7.1)	4 (57.1)	0 (0)		
D	10 (71.4)	0 (0)	3 (42.9)	0 (0)		
KT-1000 (%)					<**0.001**	>0.999
0 to 2	0 (0)	8 (57.1)	0 (0)	5 (71.4)		
3 to 5	0 (0)	5 (35.7)	0 (0)	2 (28.6)		
6 to 10	5 (35.7)	1 (7.1)	1 (14.3)	0 (0)		
> 10	9 (64.3)	0 (0)	6 (85.7)	0 (0)		
Posterior drawer (%)					<**0.001**	>0.999
Negative	0 (0)	8 (57.1)	0 (0)	5 (71.4)		
+	0 (0)	5 (35.7)	0 (0)	2 (28.6)		
++	5 (35.7)	1 (7.1)	1 (14.3)	0 (0)		
+++	9 (64.3)	0 (0)	6 (85.7)	0 (0)		

Combined injuries Variable	Group 1 (N = 20)		Group 2 (N = 11)		p_{time}	$p_{graft\ type}$
	Pre-operative	Postoperative	Pre-operative	Postoperative		
Lysholm (mean score)	42.95	91.45	48.54	94.18		
Lysholm (%)					<**0.001**	0.877
Excellent	0 (0)	7 (35)	0 (0)	7 (63.6)		
Good	1 (5)	13 (65)	0 (0)	3 (27.3)		
Regular	3 (15)	0 (0)	2 (18.2)	1 (9.1)		
Poor	16 (80)	0 (0)	9 (81.8)	0 (0)		
IKDC (%)					<**0.001**	0.545
A	0 (0)	1 (5)	0 (0)	5 (45.5)		
B	0 (0)	18 (90)	0 (0)	6 (54.5)		
C	2 (10)	1 (5)	2 (18.2)	0 (0)		
D	18 (90)	0 (0)	9 (81.8)	0 (0)		
KT-1000 (%)					<**0.001**	0.872
0 to 2	0 (0)	12 (60)	0 (0)	9 (81.8)		
3 to 5	0 (0)	8 (40)	0 (0)	2 (18.2)		
6 to 10	4 (20)	0 (0)	1 (9.1)	0 (0)		
>10	16 (80)	0 (0)	10 (90.9)	0 (0)		
Posterior drawer (%)					<**0.001**	0.808
Negative	0 (0)	12 (60)	0 (0)	10 (90.9)		
+	0 (0)	8 (40)	0 (0)	1 (9.1)		
++	3 (15)	0 (0)	0 (0)	0 (0)		
+++	17 (85)	0 (0)	11 (100)	0 (0)		

et al. compared the use of the quadriceps tendon and hamstring tendon [18]. However, using the single-bundle technique in a series of 49 cases, the authors did not find significant differences between the two types of grafts. In a more recent study, Lin et al. compared the use of hamstrings with the patellar tendon in single-bundle reconstruction [17]. The authors found significant differences in anterior symptoms, the development of degenerative changes, and lower posterior stability; all favored the hamstrings.

A complication rate of 9.6% was observed in this study, including four cases of joint stiffness. This rate is not negligible; however, it was expected since these injuries are usually generated by high-energy trauma and treated by a major surgical intervention, necessitating careful and prolonged rehabilitation. The higher occurrence of joint stiffness in group 1, although not statistically significant, was expected. Removal of the quadriceps tendon with a bone block is a procedure that violates the extensor apparatus, removing much of a tendon that is naturally subjected to great tension. Therefore, in addition to the careful postoperative protocol, which included partial immobilization for six weeks, a higher rate of joint stiffness, muscle weakness, and symptoms related to patellofemoral overload were expected in these patients. Three cases in group 1 developed symptomatic loss of range of motion (ROM), representing 8.8% of the total group, which is a high rate compared with results in the literature. Chen et al. reported a loss of ROM considered abnormal in five percent of patients undergoing reconstruction with the quadriceps tendon and four percent in those for whom hamstrings were used [18]. Chahla et al. stated that only five studies included in their systematic review reported complication rates: there were important ROM limitations in two cases of single-bundle reconstruction (one percent) and four cases of double-bundle reconstruction (two percent); pain in the donor site in two cases of single-bundle reconstruction (one percent) and in two cases of double-bundle reconstruction (one percent); pain around the surgical wound staples in two cases; a case of sympathetic reflex dystrophy in a patient undergoing single-bundle reconstruction; and one case of acute infection [9].

Lastly, the comparison between isolated and combined injuries did not show superiority of one subgroup over another, regardless of graft type or evaluation method. This finding was somewhat surprising since worse results in the combined injuries subgroup would be intuitively expected because 1) patients with multiple ligament injuries present a greater degree of instability, which is associated with greater technical difficulties for their surgical correction; and 2) the use of a semitendinosus tendon for reconstruction of the peripheral injury made the PCL graft less thick, with the PM bundle consisting of one tendon. Although conclusive statements are impossible with the available data, this finding corroborates the efficacy of hamstring tendons for reconstruction of these complex cases.

This study had some limitations. The best design with which to evaluate surgical technique and compare two graft types is a randomized clinical trial with an adequate sample size calculation. However, due to the infrequency of PCL injuries, such a study could not be performed. For the same reason and considering the even lower prevalence of isolated PCL injuries, patients with isolated and combined injuries were included, seeking to maintain the maximum possible standardization. Although homogeneity between the groups was sought, group 1 had considerably more cases than group 2 and presented a significantly higher incidence of meniscal/chondral injuries. These are factors that could potentially create bias in the comparison. Despite these limitations, this study presented a good sample size in comparison with similar studies and is among the largest available with the use of autografts. Additionally, no other study has compared the use of two types of autografts in double-bundle PCL reconstruction.

5. Conclusion

After two years of follow-up, double-bundle PCL reconstruction with autografts showed good function and stability – reflected by the 98% and 96% satisfactory results for the Lysholm score and objective IKDC score, respectively – in both isolated and combined injuries. No significant difference was observed in relation to the type of autograft used; thus, both options are feasible for the treatment of these complex cases.

Declaration of competing interest

None.

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