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Evaluation of the peroneus longus tendon as an autologous graft in knee surgery

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Our hypothesis is that the peroneus longus (PL) is a great option for ligament reconstruction in the knee, and therefore the objective of the study is to determine if the use of this graft is safe and does not cause secondary damage to the harvested area. A prospective study was conducted between April 2019 and September 2022. Patients who underwent any type of knee ligament reconstruction using the PL or just the anterior half (AHPL) as grafts were followed up. These patients were evaluated according to the Tegner–Lysholm score and the International Knee Documentation Committee (IKDC) guidelines for functional evaluation of the knee and the American Orthopedic Foot and Ankle Score (AOFAS) and the Foot and Ankle Disability Index (FADI) for the functional evaluation of the ankle. Most patients had an increase in the IKDC score, Tegner–Lysholm score, AOFAS and FADI regardless of the graft used in the surgical procedure, with mean values at the 24-month follow-up of, respectively, 99.02$\pm$ 0.02, 98.69$\pm$ 0.08, 99.92$\pm$ 0.07, and 99.92$\pm$ 0.07 for those with PL grafts and 99.31$\pm$ 0.54, 98.88$\pm$ 0.95, 100$\pm$ 0.00, and 100$\pm$ 0.00 for those with AHPL grafts. The differences in the scores between the two graft groups during each of the follow-up periods were significant (*P* = 0.001). The use of the peroneus longus tendon as a graft in knee surgeries was shown to be adequate for achieving good knee functional results.

Keywords Knee ligaments, Ankle, Multiple ligaments injury, ACL

Anterior cruciate ligament (ACL) injury is the most common knee ligament injury in patients who practice some form of sports activity and has an incidence of 78 per 100,000 people per year[1]. Patients with untreated ACL tears have a higher incidence of meniscal tears and articular cartilage damage, which may progress to knee arthrosis[2]. In addition to ACL injuries, other ligament injuries may occur in the knee, and consequently, these patients require surgical treatment with a technique that reconstructs the injured ligament.

In recent years, knee ligament reconstructions have evolved to use different types of grafts. Autografts, allografts and synthetic grafts are options with varying degrees of success in terms of clinical outcomes[3].

Autografts can be harvested from several regions. The most popular grafts among knee surgeons are flexor (hamstring tendon, HT) and patellar tendon (bone-patellar tendon-bone, BTB) grafts[4]. Each of these grafts has its advantages and disadvantages. The BTB graft is removed with bone plugs, which facilitates integration into the bone. However, complications include patellofemoral pain, patellar fracture and pain in the region of graft removal. The HT is removed more simply with little local morbidity, but it is difficult to predict the size to be obtained. Additionally, its removal may cause decreased strength, affecting the performance of athletes who use knee flexion in their sports routine[5].

The PL tendon has been considered a graft option for knee ligament reconstruction. Despite its stabilizing function for the foot and ankle, the effects of its removal do not have clinical repercussions in the short and medium term on patient gait[6,7].

The PL graft can be harvested in two ways: in its entirety or just the AHPL, depending on the characteristics of the graft required for the surgical technique to be used. Many authors use this graft to perform various types of ligament reconstructions, from ACL, posterior cruciate ligament, and medial patellofemoral ligament reconstruction to coracoclavicular ligament reconstruction in the shoulder[8–11].

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Our hypothesis is that the PL is a great option for ligament reconstruction in the knee, and therefore the objective of the study is to determine if the use of this graft is safe and does not cause secondary damage to the harvested area.

Methods

A prospective study was conducted between April 2019 and September 2022 after approval by the ethics committee of the Irmandade da Santa Casa de Misericórdia de São Paulo, under protocol 34826120.5.0000.5479 and signing of informed consent forms by the participating patients. The research was conducted in accordance with the Declaration of Helsinki. During this period, patients who underwent any type of knee ligament reconstruction using the PL or AHPL as grafts were followed up. Those who had some type of instability or previous ankle injury were excluded from the study.

A total of 155 patients were consecutively selected; two were excluded due to previous ankle instability, and six were lost to follow-up before 6 months postoperatively, and thus a total of 147 patients were analyzed. These patients were evaluated according to the Tegner–Lysholm score and the International Knee Documentation Committee (IKDC) guidelines for functional evaluation of the knee and the American Orthopedic Foot and Ankle Score (AOFAS) and the Foot and Ankle Disability Index (FADI) for the functional evaluation of the ankle. The individuals were allocated into 3 groups: Group A, 6-month follow-up (147 participants); Group B, 12-month follow-up (102 participants); and Group C, 24-month follow-up (63 participants) (Fig. 1). Group memberships could overlap; for example, participants in the 24-month follow-up group were included in the 6- and 12-month follow-up groups.

The graft was harvested using the following technique according to the surgeon's needs: an incision is made at the posterior edge of the fibula approximately 2 to 3 cm proximal to the most distal point of the lateral malleolus (Fig. 2). After dissection of the subcutaneous tissue, the PL tendon and the fibularis brevis tendon are identified and joined with nonabsorbable sutures (Fig. 3). At this point, the entire PL can be incised and removed with the aid of a tenotome (Fig. 4); alternatively, an "*L*"-shaped incision can be made in the LP tendon, separating the anterior half from the remainder of the tendon, which is then removed, also with the aid of the tenotome (Fig. 5). After harvesting the graft, the remaining tissue is sutured in layers.

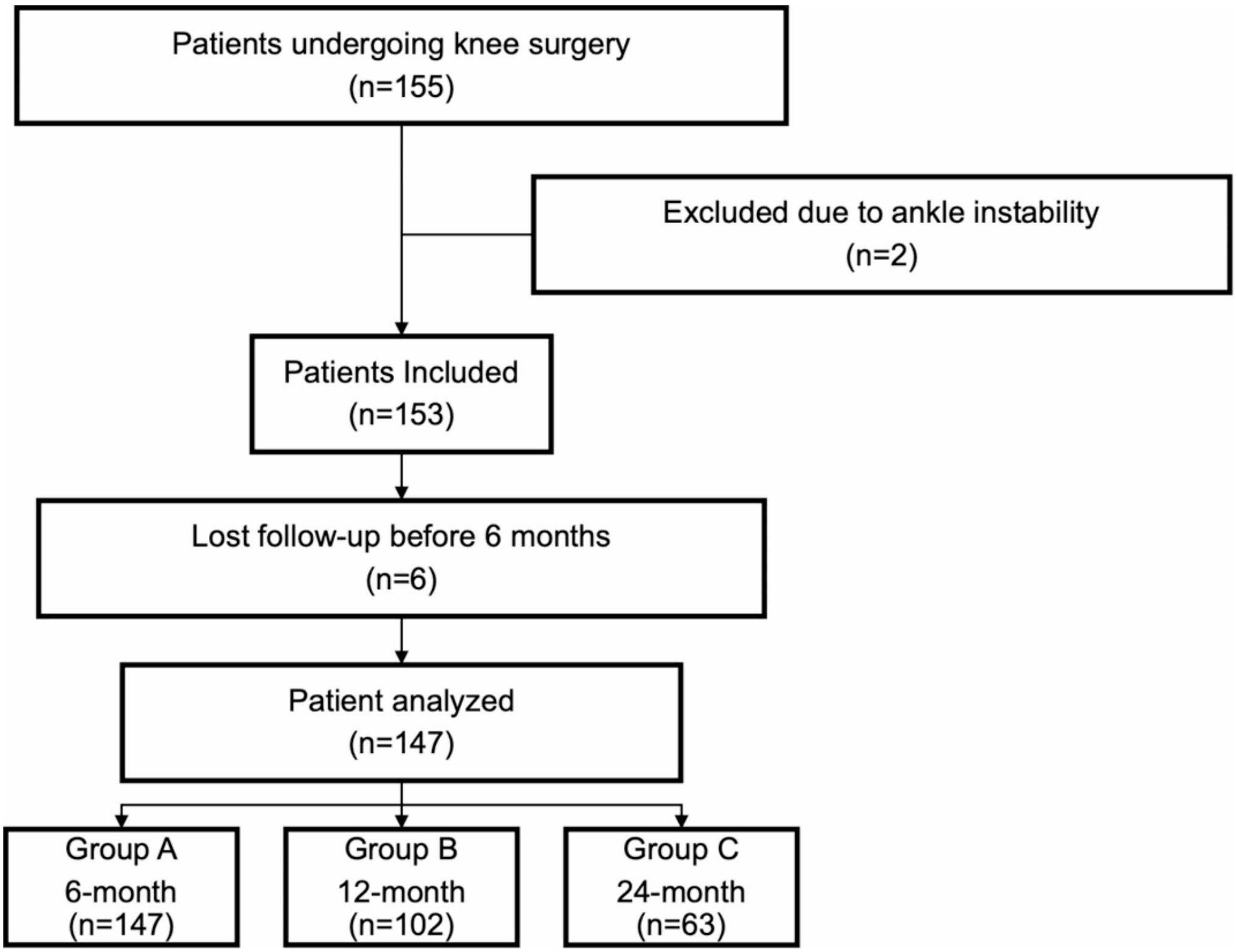

Fig. 1. Flow diagram of the study.

Fig. 2. An incision is made 3 cm from the distal part of the lateral malleolus.

Statistical analysis was performed using SPSS V26. A p value of <0.05 was considered to indicate statistical significance.

Results

The included patients had a mean age of 27.33± 7.44 years, a mean height of 173.41± 8.15 cm and an average weight of 76.49± 13.34 kg. Most of the individuals studied played soccer as their main sport (76.87%). The most frequent type of reconstruction was ACL reconstruction alone (85.71%), followed by other reconstructions. Four (3.92%) patients had failed treatment for stability 12 months after surgery (Group B), all of whom underwent ACL reconstruction. Regarding the graft donor region, 15 (10.20%) patients demonstrated swelling and hematoma formation in the first preoperative week, 3 (2.04%) patients were diagnosed with a superficial infection, and none had any Neurological deficits (Table 1).

Most patients had an increase in the IKDC score, Tegner–Lysholm score, AOFAS and FADI regardless of the graft used in the surgical procedure, with mean values at the 24-month follow-up of, respectively, 99.02± 0.02, 98.69± 0.08, 99.92± 0.07, and 99.92± 0.07 for those with PL grafts and 99.31± 0.54, 98.88± 0.95, 100± 0.00, and 100± 0.00 for those with AHPL grafts. The differences in the scores between the two graft groups during each of the follow-up periods were significant ($P=0.001$) (Table 2).

In addition to the comparison at each time point, the changes in the scores between time points were compared as follows: Delta 1 (D1): difference between 12 months and 6 months, Delta 2 (D2): difference between 24 months and 6 months and Delta 3 (D3): difference between 24 months and 12 months.

We found that for the Tegner–Lysholm score, there was no significant difference between grafts for all time points and deltas analyzed. For the IKDC score, we found differences only in D1 and D2, where we observed that there was an increase in the score for both grafts, but it was greater for the AHPL graft than for the PL graft. Analyzing the AOFAS, we found a difference only in D3, with a mean of 0.08 for PL and 0.36 for AHPL (p value = 0.046). Finally, in FADI, we observed a significant difference at 6 months and for the three Deltas evaluated. For Delta 1, for example, we observed an average increase of 0.89 for PL versus 0.16 for AHPL grafts (p value = 0.005). Table 3.

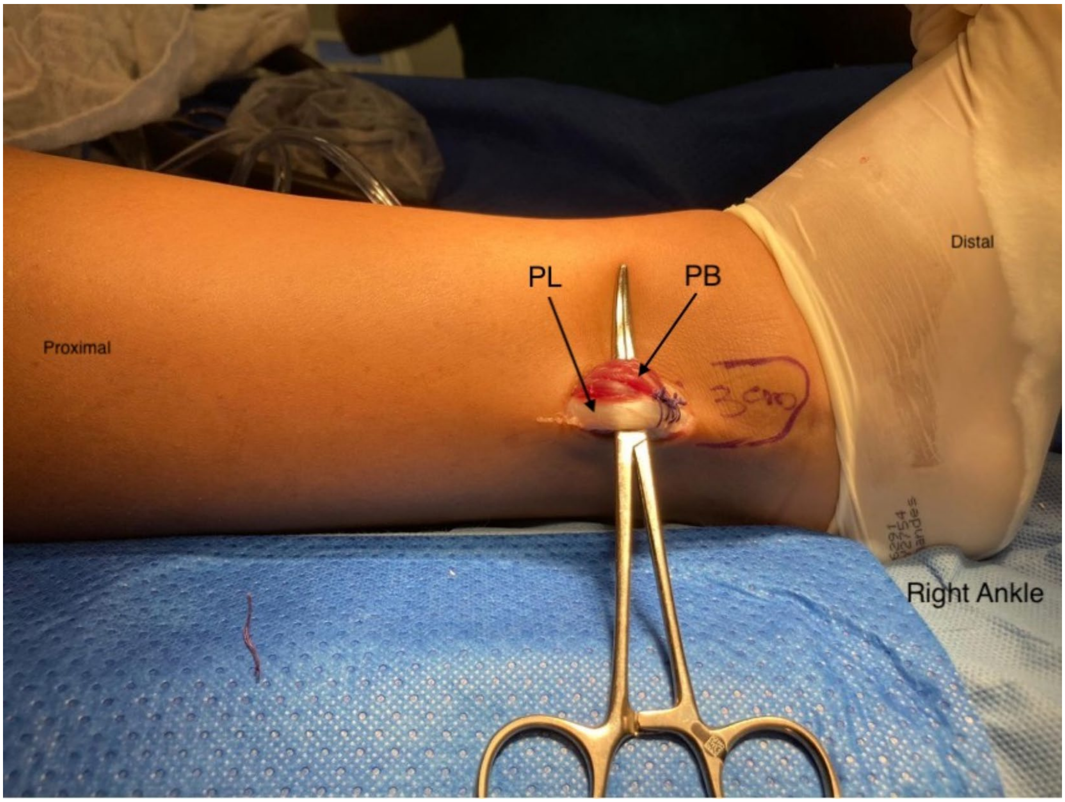

Fig. 3. The peroneus longus and peroneus brevis tendons are identified and linked.

Discussion

The most important finding of this study was that the clinical ankle scores (AOFAS and FADI) of the patients who underwent removal of the PL graft were excellent at 6 months postoperatively and remained excellent until 24 months, with a progressive increase in their results.

Some previous studies that followed up patients who underwent ACL reconstruction with the aid of PL and AHPL grafts showed similar results for the IKDC and Tegner–Lysholm scores at 6, 12 and 24 months[5,12,13]. In addition, we also found similar results for the postoperative ankle FADI and AOFAS[5,12,14,15]. However, there are few comparisons in the literature between the use of the entire PL or only its anterior half; most series used only the PL or only the AHPL[5,12–15]. According to our results, there is no difference between the choice of graft type, allowing the surgeon to choose according to their needs and those of the technique.

The complications observed in the graft donor region were of low morbidity and did not affect patient rehabilitation and the final result of the surgery, confirming the hypothesis that the graft can be safely removed.

It is still not possible to predict how ankle function will behave after 24 months, and this is a limitation of our study. Future joint degeneration may occur in the medium and long term. Some authors have cited no differences between ankle eversion strength and plantar flexion of the first ray when compared to the contralateral side[16]; others have cited that the eversion torque does not sufficiently decrease to interfere with daily and sports activities[17]. Another study limitation is the limited number of study participants.

The use of the peroneus longus tendon as a graft in knee surgeries was shown to be adequate for achieving good knee functional results. Regarding the donor site, there was no decrease in the FADI and AOFAS regardless of whether the graft was removed in its entirety. Further follow-up would be required to assess whether these excellent scores are maintained in the medium and long term.

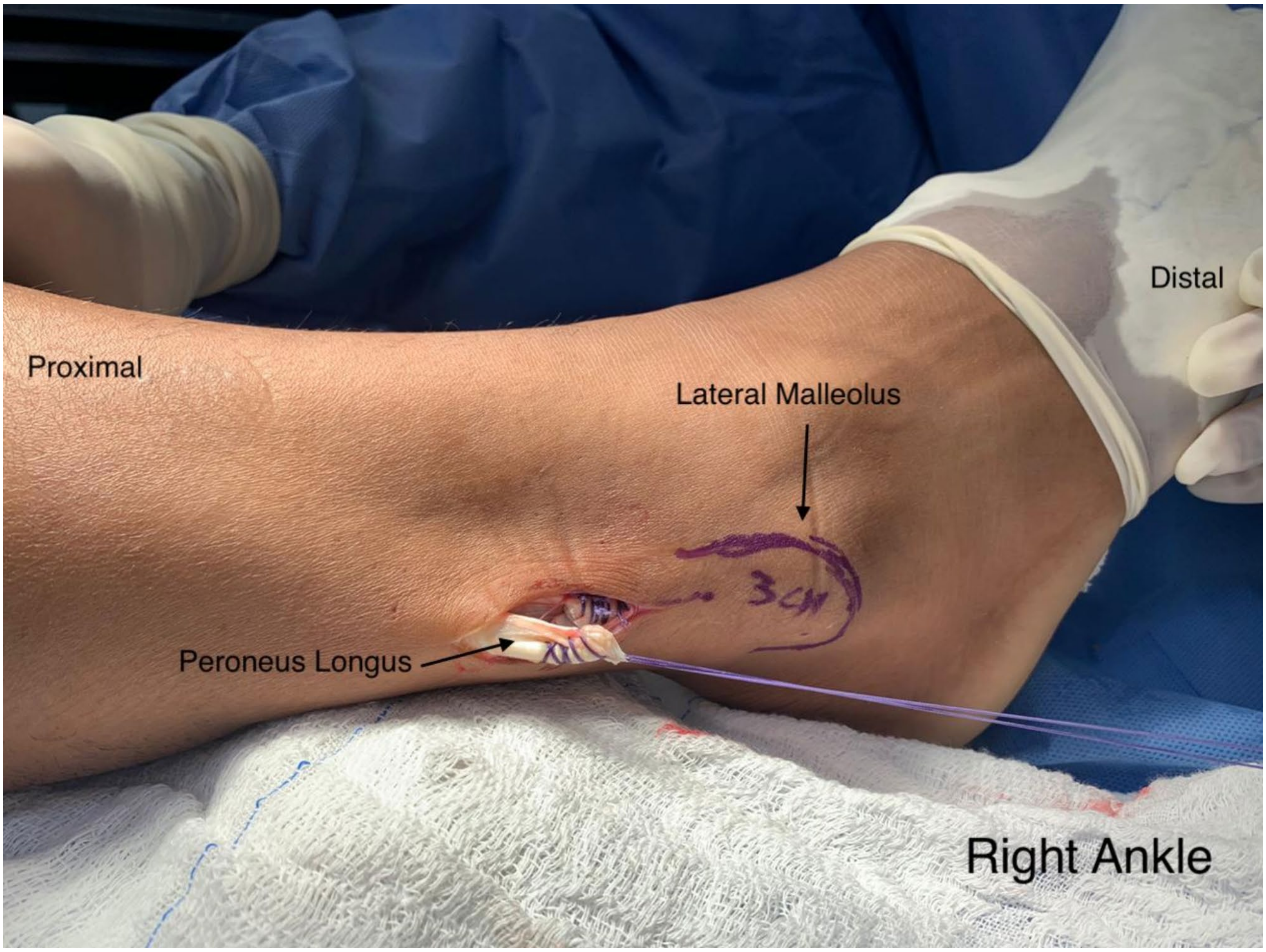

Fig. 4. The peroneus longus was completely removed in this image.

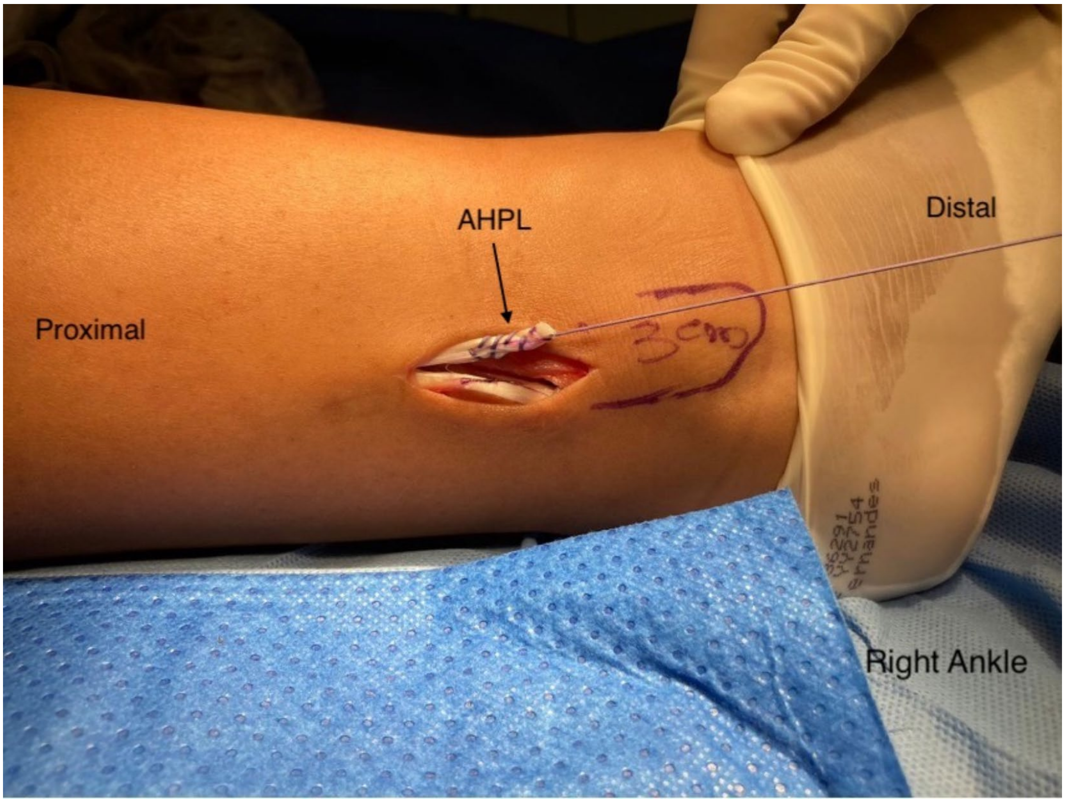

Fig. 5. The anterior half of the peroneus longus was removed in this image.

Characteristics	Group	Mean ± SD	Min	Max	*n*
Age (years)		27.33 ± 7.44	14	50	
Height (cm)		173.41 ± 8.15	154	202	
Weight (Kg)		76.49 ± 13.34	54	105	
Sports	Soccer				113 (76.87%)
	Handball				14 (9.52%)
	Basketball				9 (6.12%)
	Volleyball				3 (2.04%)
	Strength Training				3 (2.04%)
	Skateboard				3 (2.04%)
Graft	PL				75 (51.02%)
	AHPL				72 (48.98%)
Surgery	ACL-R				126 (85.71%)
	ACL-R + MCR-R				6 (4.08%)
	CORNER-R				3 (2.04%)
	ACL-R + CORNER-R				3 (2.04%)
	PFML-R				3 (2.04%)
	QUAD-R				3 (2.04%)
Post-surgical complications	Superficial infection				3 (2.04%)
	Hematoma				15 (10.20%)

Table 1. Clinical features of the patients in the study ($n = 147$). SD = standard deviation, PL = Peroneus Longus, AHPL = Anterior Half of Peroneus Longus, ACL-R = ACL reconstrucion, MCL-R = medial collateral ligament reconstruction, CORNER = posteloaeral corner recosntruction, PFML-R = patellofemoral ligament reconstruction, QUAD-R = quadriceps repair.

	Graft	Follow-up	Score Mean ± SD	Confidence interval 95%	*P*-value
IKDC	PL	6 months	89.25 ± 5.96	1.87	< 0.001
		12 months	97.41 ± 2.26	1.02	
		24 months	99.02 ± 0.02	0.32	
	AHPL	6 months	83.80 ± 9.80	3.92	< 0.001
		12 months	98.44 ± 0.86	0.74	
		24 months	99.31 ± 0.54	0.22	
Lysholm	PL	6 months	89.31 ± 5.45	1.71	< 0.001
		12 months	97.00 ± 2.44	1.08	
		24 months	98.69 ± 1.08	0.34	
	AHPL	6 months	90.00 ± 4.24	1.70	< 0.001
		12 months	96.88 ± 2.91	1.16	
		24 months	98.88 ± 0.95	0.38	
AOFAS	PL	6 months	98.72 ± 0.86	0.27	< 0.001
		12 months	99.85 ± 0.04	0.17	
		24 months	99.92 ± 0.07	0.08	
	AHPL	6 months	97.51 ± 1.87	1.95	< 0.001
		12 months	99.64 ± 0.08	0.27	
		24 months	100 ± 0.00	x	
FADI	PL	6 months	98.95 ± 0.88	0.28	< 0.001
		12 months	99.85 ± 0.04	0.17	
		24 months	99.92 ± 0.07	0.08	
	AHPL	6 months	99.47 ± 0.06	0.31	0.007
		12 months	99.63 ± 0.01	0.28	
		24 months	100 ± 0.00	X	

Table 2. Functional results at 6, 12 and 24 months after surgery. Friedman test performed to compare the 3 time points in which the scores were applied. SD = standard deviation, PL = Peroneus Longus, AHPL = Anterior Half of Peroneus Longus.

			Mean	SD	CI	*P*-value
Lysholm	6 m	PL	89.31	5.45	1.71	0.449
		AHPL	90.00	4.24	1.70	
	12 m	PL	97.00	2.44	1.08	0.739
		AHPL	96.88	2.91	1.16	
	24 m	PL	98.69	1.08	0.34	0.546
		AHPL	98.88	0.95	0.38	
	D1	PL	7.69	4.69	1.47	0.434
		AHPL	6.88	4.44	1.77	
	D2	PL	9.38	4.68	1.47	0.629
		AHPL	8.88	4.16	1.67	
	D3	PL	1.69	2.76	0.87	0.349
		AHPL	2.00	2.22	0.89	
IKDC	6 m	PL	89.25	5.96	1.87	0.070
		AHPL	83.80	9.80	3.92	
	12 m	PL	97.41	2.26	1.02	0.260
		AHPL	98.44	0.86	0.74	
	24 m	PL	99.02	0.02	0.32	0.370
		AHPL	99.31	0.54	0.22	
	D1	PL	8.15	5.73	1.80	0.008
		AHPL	1.64	9.24	3.70	
	D2	PL	9.76	5.67	1.78	0.038
		AHPL	15.51	9.68	3.87	
	D3	PL	1.61	2.35	0.74	0.141
		AHPL	0.88	1.55	0.62	
AOFAS	6 m	PL	98.72	0.86	0.27	0.269
		AHPL	97.51	2.87	1.95	
	12 m	PL	99.85	0.04	0.17	0.094
		AHPL	99.64	0.08	0.27	
	24 m	PL	99.92	0.07	0.08	0.167
		AHPL	100.00	0.00	- x -	
	D1	PL	1.13	1.06	0.33	0.357
		AHPL	2.13	4.32	1.73	
	D2	PL	1.21	0.92	0.29	0.404
		AHPL	2.49	4.87	1.95	
	D3	PL	0.08	0.27	0.08	0.046
		AHPL	0.36	0.68	0.27	
FADI	6 m	PL	98.95	0.88	0.28	0.015
		AHPL	99.47	0.06	0.31	
	12 m	PL	99.85	0.04	0.17	0.075
		AHPL	99.63	0.31	0.28	
	24 m	PL	99.92	0.07	0.08	0.167
		AHPL	100.00	0.00	- x -	
	D1	PL	0.89	1.04	0.33	0.005
		AHPL	0.16	0.99	0.40	
	D2	PL	0.97	0.93	0.29	0.038
		AHPL	0.53	0.76	0.31	
	D3	PL	0.08	0.27	0.08	0.046
		AHPL	0.38	0.71	0.28	

Table 3. Compare graft by moments to scores. Comparison of the two types of graft at each of the three moments of the four scores evaluated, using the Mann-Whitney test. SD = Standard deviation, CI = Confidence interval, PL = Peroneus Longus, AHPL = Anterior Half of Peroneus Longus.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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References

1. Nordenvall, N. et al. A population-based nationwide study of cruciate ligament injury in Sweden, 2001–2009: Incidence, Treatment, and Sex Differences'. *Am. J. Sports Med.* **40**(8), 1808–13. https://doi.org/10.1177/0363546512449306. (2012) PMID: 32523289; PMCID: PMC7275277.
2. Sanders, T. L. et al. Is Anterior Cruciate Ligament Reconstruction Effective in preventing secondary meniscal tears and osteoarthritis? *Am. J. Sports Med.* **44** (7), 1699–1707. https://doi.org/10.1177/0363546516634325 (2016).
3. Chambat, P., Guier, C., Sonnery-Cottet, B., Fayard, J. M. & Thaunat, M. The evolution of ACL reconstruction over the last fifty years. *Int. Orthop.* **37**(2), 181–186. https://doi.org/10.1007/s00264-012-1759-3 (2013). PMID: 23322063; PMCID: PMC3560904.
4. Paschos, N. K. & Howell, S. M. Anterior cruciate ligament reconstruction: principles of treatment. *EFORT Open. Rev.* **1**(11), 398–408. https://doi.org/10.1302/2058-5241.1.160032 (2017). PMID: 28461919; PMCID: PMC5367541.
5. Rhatomy, S. et al. Peroneus longus autograft can be recommended as a superior graft to hamstring tendon in single-bundle ACL reconstruction. *Knee Surg. Sports Traumatol Arthrosc.* **27**(11), 3552–3559. https://doi.org/10.1007/s00167-019-05455-w (2019). PMID: 30877316.
6. Karimi, M. et al. Gait analysis of anterior cruciate ligament reconstructed subjects with a combined tendon obtained from hamstring and peroneus longus. *Knee* **20**(6), 526–31. https://doi.org/10.1016/j.knee.2013.07.007 (2013). PMID: 23978326.
7. Nazem, K., Barzegar, M., Hosseini, A. & Karimi, M. Can we use peroneus longus in addition to hamstring tendons for anterior cruciate ligament reconstruction?. *Adv. Biomed. Res.* **3**, 115. https://doi.org/10.4103/2277-9175.132696 (2014). PMID: 24949286; PMCID: PMC4063109.
8. de Oliveira, D. E. et al. Anterior cruciate and anterolateral ligament reconstruction using hamstring and peroneus longus tendons: surgical technique description. *Arthrosc. Tech.* **10**(2), e397–e402. https://doi.org/10.1016/j.eats.2020.10.030 (2021). PMID: 33680771; PMCID: PMC7917200.
9. Jorge, P. B. et al. Anterior cruciate and anterior oblique ligament reconstruction using hamstrings and peroneus longus' anterior half grafts. *Arthrosc. Tech.* **12**(6), e861–e866. https://doi.org/10.1016/j.eats.2023.02.019 (2023). PMID: 37424635; PMCID: PMC10323729.
10. Oliveira, D. E. et al. Peroneus longus tendon graft to reconstruct the posterolateral corner of the knee. *Rev. Bras. Ortop.* https://doi.org/10.1055/s-0041-1724085 (2021).
11. Zhu, Y. et al. A prospective study of coracoclavicular ligament reconstruction with autogenous peroneus longus tendon for acromioclavicular joint dislocations. *J Shoulder Elbow Surg.* **27**(6), e178–e188. https://doi.org/10.1016/j.jse.2017.12.009 (2018). PMID: 29397294.
12. Rhatomy, S. et al. Single bundle ACL reconstruction with peroneus longus tendon graft: 2-years follow-up. *J Clin Orthop Trauma.* **11**(Suppl 3), S332–S336. https://doi.org/10.1016/j.jcot.2019.09.004 (2020). PMID: 32523289; PMCID: PMC7275277.
13. Shi, F. D. et al. Peroneus Longus tendon autograft is a safe and effective alternative for anterior cruciate ligament reconstruction. *J Knee Surg.* **32**(8), 804–811. https://doi.org/10.1055/s-0038-1669951 (2019). PMID: 30206913.
14. Bi, M. et al. All-inside single-bundle reconstruction of the anterior cruciate ligament with the anterior half of the peroneus longus tendon compared to the semitendinosus tendon: A Two-Year Follow-Up Study. *J Knee Surg.* **31**(10), 1022–1030. https://doi.org/10.1055/s-0038-1627466 (2018). PMID: 29421837.
15. Zhao, J. & Huangfu, X. The biomechanical and clinical application of using the anterior half of the peroneus longus tendon as an autograft source. *Am J Sports Med.* **40**(3), 662–71. https://doi.org/10.1177/0363546511428782 (2012). PMID: 22174343.
16. Rhatomy, S. et al. Eversion and first ray plantarflexion muscle strength in anterior cruciate ligament reconstruction using a Peroneus Longus Tendon Graft. *Orthop. J. Sports Med.* **7**(9), 2325967119872462. https://doi.org/10.1177/2325967119872462 (2019). PMID: 31632995; PMCID: PMC6767728.
17. Shao, X. et al. Satisfactory functional and MRI outcomes at the foot and ankle following harvesting of full thickness peroneus longus tendon graft. *Bone Jt. J.* **102-B**(2), 205–211. https://doi.org/10.1302/0301-620X.102B2.BJJ-2019-0949.R1 (2020). PMID: 32009424.

Author contributions

DEO: literature search, data analysis, manuscript writing. MMH and JMDM: literature search, data analysis. VBP and SMGC: conceptualization, manuscript writing, manuscript revision. PBJ: manuscript revision, supervision. All authors read and approved the final manuscript.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

Approved by the institution's ethics committee under protocol 34826120.5.0000.5479 and informed consent signed by participating patients.

Additional information

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