Orthopedic Research and Reviews

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ORIGINAL RESEARCH

Anterior Knee Pain Evaluation Following Anterior Cruciate Ligament (ACL) Reconstruction Using Anterior Half of The Peroneus Longus (AHPL) Autograft

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Introduction: The anterior cruciate ligament (ACL) is crucial for knee stability and joint movement coordination. ACL injuries are common, often leading to knee instability and subsequent complications. ACL reconstruction is a standard treatment option, with various autograft sources available. The anterior half of the peroneus longus (AHPL) tendon has emerged as a potential alternative autograft. This study aimes to examine the anterior knee pain in ACL reconstruction using AHPL.

Materials and Methods: This study included 51 patients with ACL injuries undergoing ACL reconstruction using the AHPL tendon autograft. Patient demographics, surgical details, and Kujala scores were collected.

Results: The average age of our participants was 25.88 ± 5.39 years, with mean BMI classified as obese. Significant improvements in Kujala and KOOS pain scores were observed between each data collection. There was a negative correlation between baseline and three and six months post-operatively Kujala and KOOS pain scores with BMI.

Discussion: The study findings suggest that ACL reconstruction using the AHPL tendon autograft significantly reduced anterior knee pain, as indicated by a better Kujala and KOOS pain score. Previous studies have highlighted concerns regarding anterior knee pain with other autograft sources, such as the patellar and hamstring tendons. The AHPL tendon autograft offers a promising alternative with favorable anterior knee pain and minimal donor site morbidity.

Conclusion: In ACL reconstruction, the AHPL tendon autograft demonstrates excellent outcomes regarding anterior knee pain, as measured by the Kujala score.

Keywords: anterior cruciate ligament (ACL) reconstruction, anterior knee pain, peroneus longus tendon autograft, anterior half of the peroneus longus (AHPL), Kujala score

Introduction

The anterior cruciate ligament (ACL) plays a crucial role in upholding the dynamic-static stability of the knee and ensuring coordination in knee joint movements. Its presence prevents the anterior translation of the tibia in relation to the femur, making it a vital component for the normal functioning of the knee.[1] Despite its significance, ACL injuries are prevalent, particularly among individuals engaged in organized sports or physical activities.[2,3] ACL injury, the most common ligament injury in the knee, can lead to recurrent knee instability, often resulting in osteoarthritis and meniscal

Received: 9 September 2024
Accepted: 2 February 2025
Published: 12 February 2025

tears.[4] Consequently, ACL reconstruction is frequently the treatment of choice, especially for individuals aiming to return to sports activities.[1,3,4]

Surgical procedures for ACL reconstruction involve tendon harvesting and remodelling to create the ACL graft. Grafts can be sourced from autografts, allografts, or synthetic grafts. Until now, autografts remain the most commonly utilized option compared to other graft types.[1] Various autograft options are presently employed for ACL reconstruction, notably the bone-patellar tendon-bone (BPTB), hamstring tendon (HT), and quadriceps tendon, each with its own set of advantages and disadvantages.[1,5]

Historically, BPTB autograft has been considered as the gold standard due to its excellent clinical outcomes and high level of patient satisfaction.[1] However, BPTB graft tends to cause anterior knee pain. Compared to other BPTBs, the HT graft offers better strength and fewer adverse reactions. Even though HT grafts have a significantly lower incidence of side effects, they are not necessarily spared from adverse reactions. Common adverse reactions include anterior knee pain and a significant reduction in strength at the original HT muscle site.[6,7] Additionally, with the increasing use of HT as an autograft, some shortcomings have been found in the donor site.[8] Therefore, a new autograft source will be precious to address these issues.

Recent studies have discovered that the peroneus longus tendon has the potential to replace other autografts. Peroneus longus tendon grafts have demonstrated less anterior knee pain, constituting one of their advantages.[6,7,9] However, some studies have conflicting findings, with some reporting contradictory results or no significant difference and reduced ankle function.[10] A newer study found that the anterior half of the peroneus longus (AHPL) produces less anterior knee pain while retaining ankle function, unlike using the peroneus longus tendon graft.[11] Hence, this study aims to investigate the anterior knee pain associated with the anterior half of peroneus longus tendon grafts in patients undergoing ACL reconstruction. This research is a pilot study for anterior knee pain evaluation in ACL reconstruction using AHPL tendon autograft.

Materials and Methods

This study utilized participants from medical records acquired between 2022 and 2023 in Jakarta, Indonesia. A total of 51 patients presenting with knee instability were admitted. We confirmed the ACL injury through physical and radiological examinations. All patients exhibit positive results in anterior drawer, Lachman, and pivot shift tests. Radiological confirmations were assessed through magnetic resonance imaging (MRI), demonstrating any primary signs of ACL injury. Those with concomitant ligament injury, meniscal injury, presence of fracture around the knee, history of knee surgery, and the presence of arthritis were excluded from the study. All study participants were given informed consent to be included in this study and underwent single bundle ACL reconstruction utilizing a peroneus tendon graft. One medical doctor collected baseline data such as age, sex, and BMI before the surgery. After the surgery, physical examinations such as the anterior drawer, Lachman, and pivot shift tests were also performed to confirm post-operative results. Kujala and The Knee Injury and Osteoarthritis Outcome Score (KOOS) pain score was obtained during three different periods: before surgery, three months after surgery, and six months after surgery.[12] For this study, we utilized Kujala and KOOS scores that were validated in Indonesian.[11,12] We only collected KOOS pain scores as we only wanted to evaluate the anterior knee pain following ACL reconstruction using AHPL in this study. We also collect graft diameter from each study participant. This study was conducted in compliance with the ethical principles established in the 1964 helsinki Declaration.

A single knee surgeon performed all of the surgeries. All patients underwent general and regional anesthesia to the pathological knee. Peroneus tendon graft was harvested in the ipsilateral leg. The incision was made approximately 2–3 cm superior and 1 cm posterior to the lateral malleolus[9] (Figure 1). Dissection was performed to expose the tendon from the underlying subcutaneous tissue and fascia. Once the peroneus longus and the peroneus brevis could be identified (Figure 2), the middle third of the peroneus longus was incised, separating the anterior and posterior half of the tendon (Figures 3 and 4).[11] The distal aspect of the anterior half of the peroneus longus was incised and sutured using a non-absorbable braided suture (Ethibond Excel 0). The anterior half of the peroneus longus was then harvested using the graft stripper. A landmark was identified 4–5 cm below the fibular head as the proximal point of the harvested graft to avoid injury to the peroneal nerve[9] (Figure 5). The posterior half of the peroneus longus was retained without exhibiting tissue

Figure 1 Incision posterior to the distal fibula.

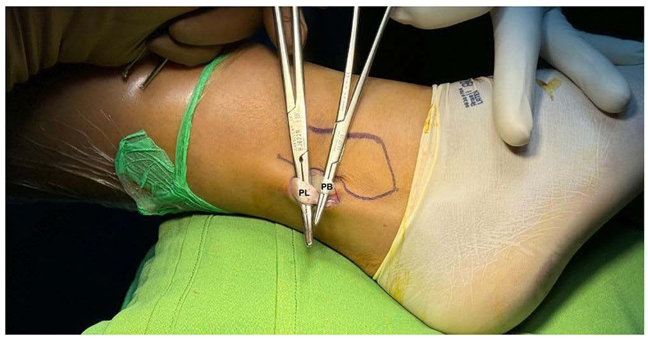

Figure 2 Identification of the peroneus longus (PL) and peroneus brevis (PB).

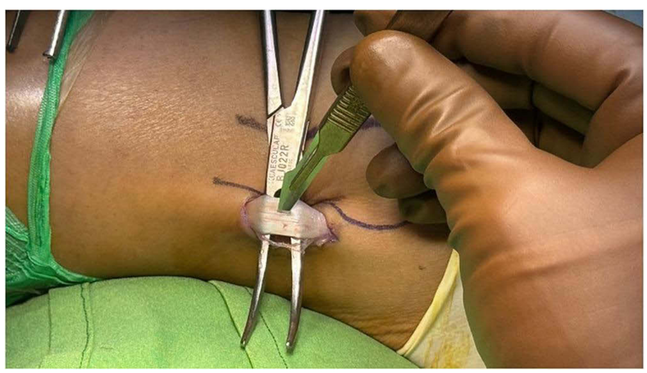

Figure 3 Incision performed in the middle part of the peroneus longus parallel to the fiber, separating anterior and posterior half fiber.

laxity (Figure 6). After the graft was harvested, the fascia previously dissected was repaired using an absorbable braided suture (Vicryl 4–0) with a continuous interlocking pattern to prevent future herniation of the peroneus tendons.

Arthroscopic portals were made at the anterolateral and anteromedial segments of the knee inferior to the patella. Arthroscopic debridement of the fibrous tissue surrounding the injured ACL fibers and the intercondylar notch was performed to provide good visualization of the tunnel site. The remnants of the ACL fiber were retained as a reference marker for the graft implant. Before graft implantation, the graft was tensioned to prevent loosening post-operatively. Fixation was performed using a bio-absorbable screw (Bioscrew, Conmed USA) in the tibia and a button (XO Button, Conmed USA) in the femur.

The general characteristics were statistically analyzed using descriptive analysis. The normality test was analyzed using the Shapiro–Wilk test. Kujala and KOOS pain scores before surgery, three months post-operative, and six months post-operative were analyzed using repeated measures ANOVA. We conducted a paired *t*-test sample to compare each

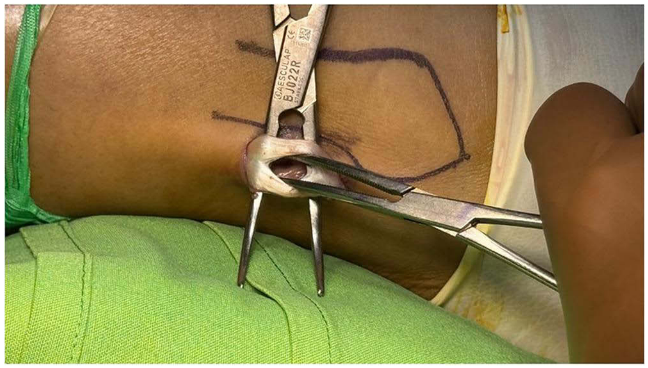

Figure 4 Anterior and posterior half of peroneus longus separation.

Figure 5 The anterior half of the peroneus longus was harvested using graft stripper. The assisting operator hold their arms approximately 4–5 cm below the fibular head to prevent injury to the peroneal nerve.

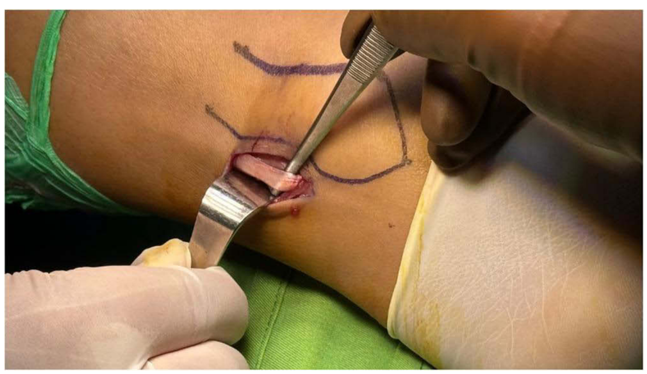

Figure 6 The posterior half of the peroneus longus was preserved.

time point to identify the time when there was a significant increase. The correlation between Kujala scores, KOOS pain scores, age, sex, BMI, and graft diameter was analyzed using the Pearson correlation test. All statistical analyses were computed using the SPSS version 27.

Results

Table 1 elaborates on the general characteristics of the study populations. Most of the study populations are young adults (25.88 ± 5.39) with male sex [40 (78%)]. The study's mean body mass index (BMI) is 25.27 ± 3.73 kg/m^2 averaging as obese in the Asia-Pacific population with a mean graft size of 7.17 ± 0.24 mm.

Table 1 General Characteristics of the Study Populations

Characteristics	N=51
Male	40 (78)
Age*	25.88 (5.39)
BMI**	25.27 (3.73)
Graft size***	7.17 (0.24)

Notes: *Age presented in years. **BMI presented in kg/m^2. ***Graft size presented in millimeter (mm). Data presented as mean (SD) or n (%).

All patients tested negative for anterior drawer, Lachman, and pivot shift test at the fourth month post-operatively, indicating normal findings for the physical examination in all study subjects. However, we did not perform a knee MRI evaluation following the surgery because it is uncommon in our country to perform a knee MRI evaluation following ACL reconstruction and because of monetary limitations.

No complications were recorded during or after the surgery. However, following the surgery, three patients were suffering from ankle pain during follow-up one month after the operation. After thorough physical rehabilitation, all patients recovered from the ankle pain.

Table 2 shows repeated measures ANOVA results of the Kujala and KOOS pain scores obtained from the study subjects. Sphericity was achieved from both Kujala and KOOS pain score results ($P > 0.05$). There were significant differences in both Kujala and KOOS pain scores, indicating a significant improvement in anterior knee pain through both evaluations.

In Table 3, we identify significant changes in Kujala and KOOS pain score already occurred between the baseline compared to the 3-months post-surgery. Hence, there was also a significant difference between the Kujala and KOOS pain score in the baseline compared to the 6-months post-surgery. Figure 7 showed Kujala and KOOS pain score evaluation through time.

Supplementary Table 1 demonstrates the correlation between Kujala and KOOS pain score evaluations and the study subjects' age, sex, BMI, and graft diameter. There is no significant correlation between the Kujala and KOOS pain scores and graft diameter. However, a negative correlation was seen between the Kujala and KOOS pain scores and BMI.

Discussion

The main findings in this study indicate a significant improvement in the Kujala and KOOS pain scores obtained before the surgery, three months, and six months post-surgery, marked by the significant difference in repeated measures ANOVA results ($P < 0.05$). A significant improvement can also be observed 3 months post-surgery, as demonstrated in

Table 2 Repeated Measures ANOVA Results of Kujala and KOOS Pain Score in Different Time Period

Evaluation	Baseline	3-Months Post-Surgery	6-Months Post-Surgery	P-Value
Kujala score	66.13 ± 4.07	73.8 ± 4.62	83.59 ± 4.49	< 0.01
KOOS pain score	58.72 ± 2.34	74.73 ± 2.91	81.88 ± 3.02	< 0.01

Table 3 Paired Sample *t*-Test Results of Kujala and KOOS Pain Score in Different Time Period

Evaluation	Baseline	3-Months Post-Surgery	P-value	6-Months Post-Surgery	P-Value
Kujala score	66.13 ± 4.07	73.8 ± 4.62	< 0.01	83.59 ± 4.49	< 0.01
KOOS pain score	58.72 ± 2.34	74.73 ± 2.91	< 0.01	81.88 ± 3.02	< 0.01

 https://doi.org/10.2147/ORR.S495410

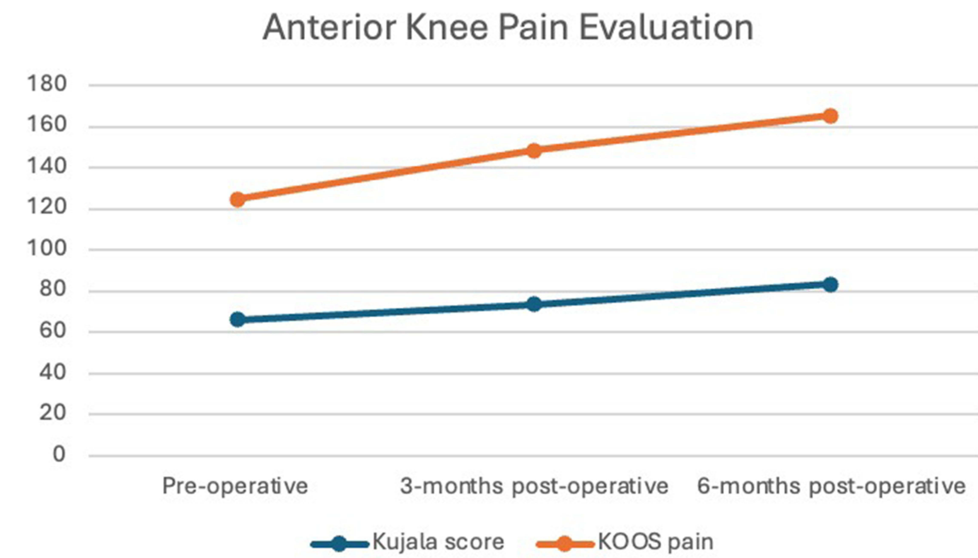

Figure 7 Anterior Knee Pain Evaluation Through Time.

paired sample *t*-test results for Kujala and KOOS pain scores ($P < 0.05$). These findings highlight the beneficial impact of the distant graft harvest site in reducing anterior knee pain. Other findings demonstrated a significant correlation between a higher Kujala and KOOS pain score and a lower BMI.

Peroneus longus tendon autograft is considered an excellent alternative to hamstring tendon autograft. It is considered to benefit from a small surgical incision, relatively easy graft identification, and minor donor site complications. However, there were concerns about the effect of peroneus longus autograft harvest on ankle functions.[13,14] Peroneus longus aids in eversion and plantarflexion, hence providing ankle stability. Some surgeons used mitigations as to preserve ankle function, such as suturing the distal end of the peroneus longus tendon and incorporating it with the peroneus brevis tendon.[9,15] Another method to preserve ankle function is by retaining some parts of the peroneus longus tendon by harvesting only half of the peroneus longus, known as the AHPL tendon autograft.[16,17] This method achieves the preservation of half of the peroneus longus, supporting the native function of the peroneus longus. A study by Gunadham et al demonstrated the AHPL tendon as an alternative autograft for ACL reconstruction with a reduction of donor site morbidity.[16]

However, there was a concern regarding small graft diameter, especially in short and thin female populations. Despite the apprehension of smaller grafts, the average size of graft in our study was 7.17 ± 0.24 mm, in which graft diameter >7 mm for ACL reconstruction was considered to have a lower risk of future ACL revision as well as better subjective score in terms of pain and function.[18,19] Zhao et al examined the use of the AHPL tendon graft for ACL reconstruction and signified no difference statistically between those underwent surgery and those healthy control in terms of ankle function demonstrated through the American Orthopaedic Foot and Ankle Society (AOFAS) score.[11] Although no changes occurred in foot morphology and gait parameters, those with the AHPL tendon autograft influenced the gait cycle.[11]

Anterior knee pain has been one of the many challenges occurring in patients undergoing ACL reconstruction surgery. The nature of patellofemoral pain syndrome (PFPS) and ACL injury shared similar biomechanics. It is agreed that high load of abduction and shallow flexion angle of the knee contributes to ACL injury and PFPS.[20] Increased knee abduction is also correlated with weak hip musculature and lower extremity postures, leading to strain increment of the ACL and the patellofemoral joint. In addition, obesity remained a risk factor for PFPS which is consistent with the results of our study. There were debates regarding autograft selections as one of the causes of anterior knee pain in those undergoing ACL reconstruction.

Historically, patellar tendon autograft or BPTB has been the graft of choice for ACL reconstruction. However, concerns arise regarding the increasing incidence of anterior knee pain following ACL reconstruction.[21,22] Marques et al compared those undergoing ACL reconstruction using patellar BPTB graft and hamstring graft, in which subjects that utilized BPTB graft were 3.4 times more likely to have anterior knee pain. Furthermore, the extension of ROM limitation leads to a higher occurrence of anterior knee pain as high as 5.3 times.[23] As the middle third of the patellar tendon is removed, the knee will have a reduced extensor mechanism and stiffness of the tendon. Both reduced extensor mechanism and tendon stiffness pose as a risk factor for anterior knee pain.[23–25] Another study by Janani et al harvested BTPB graft using a mini-open mobile window method in order to reduce graft site morbidity with no significant difference within three months after ACL reconstruction surgery in the occurrence of anterior knee pain (28.9% vs 25.5%, p = 0.22), International Knee Documentation Committee (IKDC) subjective score (54.1 ± 12.8 vs 53.6 ± 7.9, p = 0.405), and Lysholm score (73.4 ± 9.2 vs 74.5 ± 11.7, p = 0.065) compared to hamstring autograft.[26] Borges et al performed ACL reconstruction using BPTB from the contralateral knee and compared it to the ipsilateral BPTB.[27] A higher Kujala score was statistically significant in the contralateral knee compared to the ipsilateral knee. Other proposed mechanisms underlying the cause of anterior knee pain when using BTPB autografts include saphenous nerve branch injury and bony defect.[28] Hamstring autograft is also a common graft choice for ACL reconstruction. The harvesting process requires a relatively small incision with less donor site morbidity compared to a BPTB graft. Even so, there were reported cases of anterior knee pain following ACL reconstruction utilizing hamstring autograft, which differed widely in the number of occurrences ranging from 6% to 77% in previous studies.[29–31] However, compared to the BPTB graft, there was a decreasing incidence of anterior knee pain in several hamstring graft studies. Marques et al compared ACL reconstruction surgery using hamstring and BTPB grafts and demonstrated a lower prevalence of anterior knee pain in the hamstring graft group (p<0.011).[23] The underlying mechanism for the occurrence of anterior knee pain in ACL reconstruction using a hamstring graft is due to reduced internal rotation. Tibiofemoral internal prevents patellar lateral shift, leading to anterior knee pain.[6,30] Pontoh et al previously described a method of applying external rotation for the tibial fixation in ACL reconstruction using a hamstring graft. The effect of this method mitigates the patellofemoral parameters in which a lower TT-TG value (p = 0.015) in magnetic resonance imaging (MRI) and a higher Kujala score (p = 0.028) compared to control.[32]

Several studies have described the peroneus longus graft as a reliable graft to be utilized as an alternative to BPTB and hamstring graft, with several studies demonstrating fewer anterior knee pain symptoms.[33] In Phatama et al's study, the use of peroneus longus autograft has been shown to exhibit less anterior knee pain through Kujala score in 3–6 weeks post-operatively compared to hamstring graft autograft (93.53 ± 5.84 vs 71.44 ± 10.89, p < 001).[6] However, there is still limited evidence regarding the use of the AHPL tendon in ACL reconstruction. In this study, we acquired Kujala scores 3 months and 6 months post-surgery, 73.8 ± 4.62 and 83.59 ± 4.49 consecutively. Indicating that the Kujala score obtained from ACL reconstruction using the AHPL tendon has comparable results with ACL reconstruction using peroneus longus tendon autograft. In a study by Zhang et al, there was a significant improvement in KOOS pain in pre-operative Vs 6-months post-operative (60.2 ± 5.9 vs 90.3 ± 6.5) and pre-operative Vs 12 months post-operative (60.2 ± 5.9 vs 94.0 ± 5.9) using peroneus longus as their autograft.[34] In this study, we also obtained a significant improvement in the KOOS pain score during 3 months (58.73 ± 2.34 Vs 74.73 ± 2.91) and 6 months post-surgery (58.73 ± 2.34 Vs 81.88 ± 3.02).

Table 4 Comparisons of Kujala and KOOS Pain Score Evaluation Using Other Grafts

Author	Graft	Time to Follow-Up	Evaluation	
			Kujala Score	**KOOS Pain Score**
Present study	AHPL	3-months	73.8 ± 4.62	74.73 ± 2.91
		6-months	83.59 ± 4.49	81.88 ± 3.02
Phatama et al[6]	PL	6 to 12-months	93.53 ± 5.84	-
	Hamstring	6 to 12-months	71.44 ± 10.89	-
Zhang et al[34]	PL	6-months	-	90.3 ± 6.5

(*Continued*)

Table 4 (Continued).

Author	Graft	Time to Follow-Up	Evaluation	
			Kujala Score	KOOS Pain Score
		12-months	-	94.0 ± 5.9
Shahpari et al[36]	Hamstring	12-months	-	73.42 ± 20.25
Lind et al[35]	Quadriceps	12-months	83 ± 13	87 ± 12
	Hamstring	12-months	84 ± 16	88 ± 13
Witvrouw et al[37]	BPTB	3-months	68.5 ± 13.4	-
	Hamstring	3-months	65.7 ± 14.7	-
	BPTB	6-months	81.1 ± 12.5	-
	Hamstring	6-months	78.3 ± 17.2	-

As demonstrated in Table 4, this study's findings have comparable results compared with previous studies using other grafts. However, some studies may produce better results due to the longer follow-up time, such as the studies by Zhang et al[34] and Lind et al.[35] Hence, longer follow-up time is important for future studies of ACL reconstruction using the AHPL tendon grafts.

For the functional outcome, Rhatomy et al demonstrated significant improvement of functional outcome of using peroneus longus autograft in 2 years follow-up as demonstrated in IKDC (54,66 ± 14.02 vs 95.69 ± 3.35, $p < 0.001$), modified Cincinnati (65,45 ± 14.02 vs 93.29 ±7.04, $p < 0.001$), and Tegner-lysholm (65,45 ± 14.02 vs 93.29 ±7.04, $p < 0.001$) score.[9] A study by Budhiparama et al described that the use of peroneus longus autograft has no significant impact on ankle function, as seen in the AOFAS score of 97.3 ± 4.2 and Foot and Ankle Disability Index (FADI) score of 98.0 ± 3.4.[8] Anterior half of the peroneus longus has also seen an improvement in functional outcome in 3 months post-operatively illustrated in IKDC (63% vs 47.1%) and Lysholm (95% vs 47%) with no difference in AOFAS and FADI score.[38] A similar result was also seen in a study by Trung et al, with an improvement in Lysholm score from 59.0 to 94.27 6 months post-operatively with no difference in AOFAS and FADI score.[39] A different study conducted by Gunadham et al demonstrated a significantly lower IKDC score in ACL reconstruction utilizing the anterior half of the peroneus longus compared to hamstring autograft ($p < 0.0153$).[16] The anterior half of the peroneus longus autograft also demonstrated a similar IKDC score compared to the semitendinosus autograft (89.3 ± 8.4 vs 90.4 ± 7.1) with no significant difference in AOFAS score (99.1 ± 1.40 vs 99.5 ± 1.21).[40]

In this study, we found three patients had ankle pain following the surgery. After one month of rehabilitation process, none of the complaints remained. Ankle pain that occurred in our patients may be due to iatrogenic sural nerve injuries that might be related to the location of the distal incision.[41] Knowing the previous location could result in ankle pain, we changed the harvest location to 4 centimetres above the lateral malleolus to reduce the possibility of injuring the terminal branch of the sural nerve. However, changing the incision location may lead to a smaller graft diameter.[41] In response to this problem, we fold the graft into trifolds so that we acquire an adequate graft diameter. After changing the harvest location, there was no complaint regarding ankle pain. Thus, there was no significant disturbance in ankle function in this study. However, we did not evaluate patients' functional outcome scores such as IKDC, AOFAS, and FADI in this research.

Currently, no studies outline anterior knee pain in ACL reconstruction using the AHPL autograft. This study successfully became a pilot study for anterior knee pain evaluation for ACL reconstruction using the AHPL tendon autograft. Our study provided anterior knee pain assessment by utilizing the Kujala score as a subjective surrogate to evaluate anterior knee pain pre-operatively and post-operatively. However, there are some limitations to be addressed in

 https://doi.org/10.2147/ORR.S495410

the current study. First, we could not compare the autograft to other autograft such as hamstring and BPTB. This limitation disallows authors to directly compare the anterior half of the peroneus longus autograft to the hamstring or BTPB autograft that has been previously reported to have a higher rate of anterior knee pain. The other limitation includes a more thorough evaluation to perform measurements of a more direct assessment, such as an MRI examination of patellofemoral evaluations, which should be included to evaluate the correlation to anterior knee pain. In this study, we did not perform an MRI evaluation post-surgery due to financial limitations, and it is not routinely performed in our country to evaluate post-operatively. Radiological evaluation is only indicated for patients with severe pain or swelling in the operative site.

In conclusion, the AHPL tendon autograft can be an alternative graft with an excellent outcome for anterior knee pain measured through Kujala and KOOS pain scores. Even with only half of the peroneus longus tendon harvested, the autograft provides adequate graft diameter to prevent graft failure or revision surgery with minimal morbidities.

Ethical Clearance

Ethical clearance of this study was obtained from Fatmawati National Hospital with ethical number PP.08.02/D.XXI.18/127/2024.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

There is no funding to report.

Disclosure

The authors report no conflicts of interest in this work.

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