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CLINICAL ARTICLE

The Efficacy of Anterior Cruciate Ligament Reconstruction with Peroneus Longus Tendon and its Impact on Ankle Joint Function

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Objective: Peroneus Longus Tendon (PLT), a viable anterior cruciate ligament (ACL) graft, shares similar biomechanics, making it suitable for reconstruction. Controversy exists over whether PLT transplants affects the donor ankle joint. The purpose of this study was to examine the recovery of knee joint function following arthroscopic ACL restoration using autologous PLT and its influence on the donor ankle joint.

Methods: A retrospective analysis was conducted on 65 patients with ACL rupture who underwent PLT graft reconstruction in our hospital from January 2016 to December 2021. A three-dimensional gait analysis of the bilateral knee and ankle joints was performed postoperatively using an Opti_Knee three-dimensional motion measurement and analysis system—Yidong Medical Infrared Motion Gait Analyzer. Knee function scores and changes in the range of motion of the bilateral knee and ankle joints were collected. The analysis of preoperative and postoperative joint function scores, bilateral knee and ankle mobility was performed by *t*-tests.

Results: One year after surgery, the patients' International Knee Documentation Committee (IKDC) scores, Knee Injury and Osteoarthritis Outcome Scores (KOOSs), and Lysholm scores were significantly improved compared to preoperative scores, with statistically significant differences ($p < 0.05$). There was no statistical difference in the American Orthopedic Foot and Ankle Society (AOFAS) score of the donor ankle joint before and after surgery ($p > 0.05$). During different gait cycles, there was no statistical difference in knee joint mobility between the affected and healthy sides ($p > 0.05$), but there was a statistical difference in the inversion and eversion angle of the donor ankle joint during the support phase ($p < 0.05$).

Conclusion: ACL reconstruction using the PLT can yield satisfactory knee joint function. However, it does affect inversion and eversion in the donor ankle joint, necessitating postoperative exercises. Similar subjective function ratings for both operated and non-operated feet, despite increased inversion-eversion motion in the operated foot, may be influenced by the subjective nature and margin of error in the AOFAS Ankle-hindfoot score, along with the relatively small variation in ankle inversion-eversion angles.

Key words: Anterior cruciate ligament reconstruction; Arthroscopy; Knee function scores; Peroneus longus tendon; Three-dimensional gait analysis

Introduction

The anterior cruciate ligament (ACL) is an important anatomical structure for maintaining knee joint stability and movement.[1] The rupture of ACL not only affects the stability of the knee joint but also restricts normal knee movement, accelerates knee degeneration, and eventually leads to osteoarthritis of the knee joint. The main treatment for ACL rupture is arthroscopic ligament reconstruction surgery.[2] The optimal reconstruction material should have sufficient length and diameter, as well as similar physiological functions to the original ACL.[3,4]

The peroneus longus tendon (PLT) has been used for ACL reconstruction in recent years. This tendon is superficially

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located and easy to harvest. Biomechanical experiments have proven that PLT has similar biomechanical properties to ACLs and can be used as a graft substitute for cross-ligament-reconstruction.[5] Study has shown ACL reconstruction with peroneus longus autograft has excellent functional score in International Knee Documentation Committee (IKDC), Modified Cincinnati, Tegner-Lysholm score with the advantages of greater graft diameter, less thigh hypotrophy, good serial hop test result, and excellent ankle function based on American Orthopedic Foot and Ankle Society (AOFAS) and Foot and Ankle Disability Index (FADI) score.[6] Angthong *et al.*[7] suggested potential complications in the donor site, including decreased average peak torque in foot eversion and plantarflexion, as well as reduced ankle joint function and stability, discouraging the use of PLT as the primary graft. However, Angthong's study had a small sample size and short follow-up duration, warranting further research with increased cases and extended follow-up. In contrast, Goyal *et al.* and Shi *et al.*[8,9] reported no complications in the donor ankle joint among patients with autograft PLT, indicating a contentious understanding of ankle function after autograft PLT.

ACL reconstruction aims to restore function using suitable materials. PLT has emerged as a potential graft due to its biomechanical similarity to ACLs. At present, most studies mainly discuss the changes of donor ankle function through subjective ankle function score and static measurement of arch shape. The data of donor ankle motion under physiological conditions is lacking. In this study, the subjective function score of the ankle joint was obtained during follow-up visits, and the range of motion of the ankle joint at the donor area during different gait cycles was accurately measured by three-dimensional high-speed infrared camera. The data are visualized and concrete, and the functional changes of the ankle joint at the donor area may be more accurately evaluated.

We analyzed clinical data from patients who had arthroscopic ACL restoration with autologous PLT in our facility between January 2016 and December 2021 to confirm the following items: (i) functional changes of PLT as a graft substitute for ACL knee reconstruction; (ii) the changes in ankle function in the donor area after definitive PLT excision; (iii) exploring postoperative rehabilitation management based on the functional changes of the ankle in the donor area after PLT excision.

Patients and Methods

General Information

This research conformed to the provisions of the Declaration of Helsinki (as revised in 2013). This research was approved by the Institutional Ethical Committee of Jinshan Hospital of Fudan University (No. JIEC-2020-S06). Each participant has provided written informed consent. Patient anonymity has been preserved.

The clinical data of patients who underwent arthroscopic ACL reconstruction with autologous PLT in our hospital from January 2016 to December 2021 were retrospectively collected. All patients understood the treatment method before surgery and signed an informed consent form. This group included 65 cases in total, 40 males and 25 females. The age ranged from 16 to 58 years old with an average age of 31.1 years old. There were 37 cases of left knees and 28 cases of right knees. Causes of injury included sports injuries in 32 cases, traffic accidents in 24 cases, and heavy object injuries in nine cases.

Inclusion Criteria & Exclusion Criteria

Inclusion criteria: (1) Clear history of knee joint trauma; (2) Positive anterior drawer test, Lachman test, pivot shift test; (3) MR and arthroscopy confirmed as ACL rupture patients; (4) Graft substitute is ipsilateral PLT. Exclusion criteria: (1)Accompanied by posterior cruciate ligament (PCL) rupture or medial/lateral collateral ligament or patellar support band rupture; (2) Accompanied by peri-knee fractures; (3) Accompanied by serious skeletal muscle and nerve diseases such as osteoarthritis, femoral head necrosis, tuberculosis, lumbar disc herniation, diabetic foot etc., on the same side or opposite side;(4) History of cerebral infarction and abnormal muscle strength sensation in the lower limbs.

Surgical Method

All surgeries were performed by the same surgeon. A single-bundle multi-strand PLT was used for anatomical ACL reconstruction, and the internal fixation materials used were the Endobutton plate and BioRCI interface screw produced by Smith & Nephew Endoscopy (Andover, MA, USA).

Arthroscopic Examination

After general anesthesia, the patient was placed in the supine position, and a tourniquet was placed at the upper third of the thigh on the affected side. The anterolateral and anteromedial portals for arthroscopic surgery were established. The arthroscope (Smith & Nephew ArthroscopeSys System, USA) was inserted from the anterolateral portal, and the ACL rupture was confirmed by careful examination.

PLT Harvesting

A longitudinal incision about 2 cm long was made at a point 1 cm posterior and 2–3 cm superior to the lateral malleolus of the affected limb. The long peroneal tendon and short peroneal tendon were exposed layer by layer. The distal end of the PLT was cut off, and the proximal end was carefully stripped to a point 4–5 cm from the head of the fibula with a stripper to avoid damaging the common peroneal nerve. The harvested long peroneal tendon was braided for later use.

Establishment of Bone Tunnel

(1) Creation of tibial bone tunnel: The residual ACL on the tibial side was preserved, and the angle of the tibial guide was adjusted to 55°. The distal tunnel entrance was located 1.5 cm medial to the tibial tubercle, and the proximal opening was at the intersection of the extension line of the

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anterior horn of the lateral meniscus and the intercondylar ridge, about 7 mm anterior to the PCL tibial stop point. A guide pin was drilled in at an angle of 40–55° to the sagittal plane of the tibia, and after confirming a good needle exit position, a drill bit matching the tendon diameter was used to create a tibial bone tunnel. (2) Creation of Femoral bone tunnel: The Femoral tunnel was established through the tibial bone tunnel method. After clearing blood clots and synovial tissue, a mark was made in the area of ACL footprint on lateral wall of intercondylar fossa behind lateral intercondylar tubercle, and a femoral locator was placed. With knee flexed at 90°, a guide pin was inserted from tibial bone tunnel into femoral marking point and pierced out through skin in upper outer direction from femoral condyle. A 4.5 mm drill bit was used to create Femoral bone tunnel, depth measured after which femoral drill bit matching tendon diameter was chosen, depth about 20–25 mm, traction wire passed through tibial Femoral bone tunnel for standby.

Ligament Reconstruction

The PLT was braided into three or four strands according to its diameter, with a diameter between 8.0–9 mm after braiding. The tendon was fixed on a loop, and prepared tendon passed through traction wire from inside tibial and femoral bone tunnels until Endobutton plate pulled out from cortical bone outside femur. Tendon tightened through traction wire confirmed Endobutton plate flipped then fixed ligament on tibial side with polylactic acid hydroxyapatite screw, external nail reinforced fixation braided tendon line. Flexed knee joint repeatedly performed drawer test inspection after confirming function unobstructed then sutured incision, elastic bandage wrapped around knee joint brace worn (typical case see Figure 1).

Postoperative Rehabilitation Regimen

All enrolled individuals underwent a standardized postoperative rehabilitation protocol. Subsequent to the surgical procedure, the knee joint received treatment involving elastic bandage compression and cryotherapy to mitigate edema. Mobilization of the toe and ankle joints commenced promptly upon emergence from anesthesia. Between postoperative days 1 to 3, a series of exercises, including ankle pumps, quadriceps and hamstring contractions, as well as straight leg raises, side leg lifts, and posterior leg lifts, were initiated. An activity brace was applied to afford protection to the knee joint. Initiation of non-weight-bearing knee joint range of motion exercises occurred 1 week post-surgery. By weeks 1 to 4, the degree of knee flexion achieved 90°, surpassing 90° by the fourth week, with partial weight-bearing

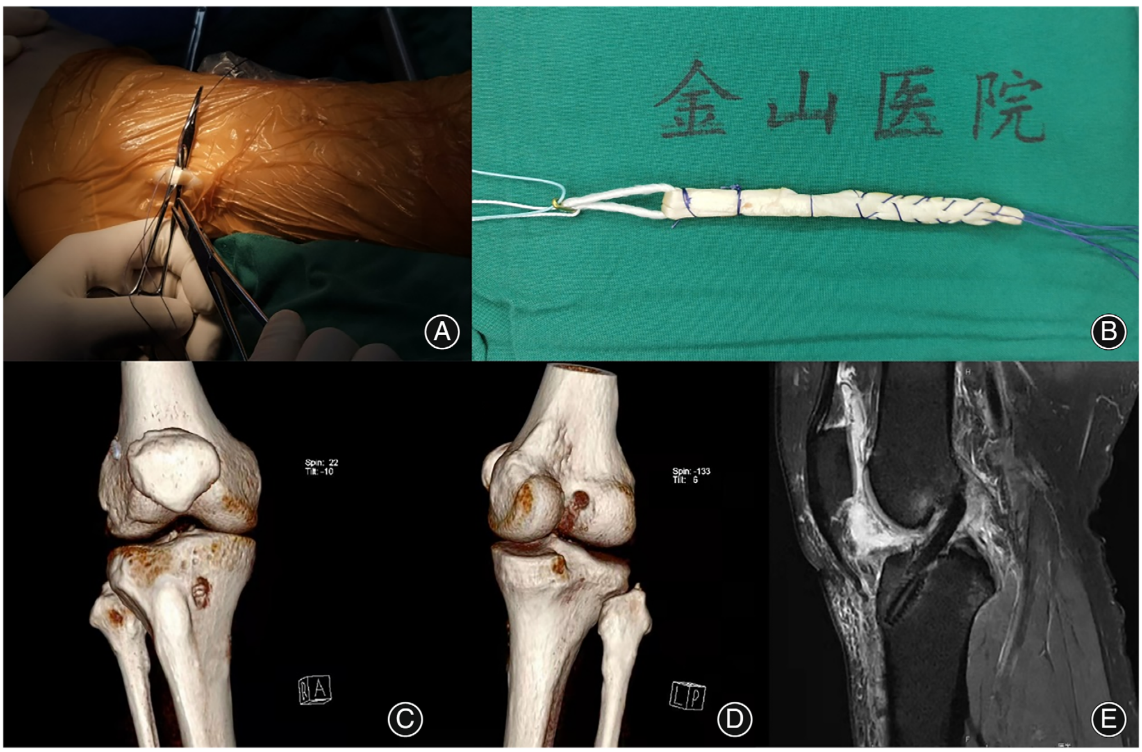

Figure 1 A typical case of a 31-year-old male with a ruptured right anterior cruciate ligament. (A) Harvesting of the long peroneal tendon; (B) The free long peroneal tendon after braiding; (C) Three-dimensional reconstruction of the tibial bone tunnel and the position of the endobutton plate; (D) Three-dimensional reconstruction of the femoral bone tunnel; (E) Postoperative MR indicates satisfactory graft position and good continuity.

initiated under brace protection. Gradual advancement to normal activity levels and full weight-bearing, under brace protection, commenced after 8 weeks post-surgery. Resumption of daily activities occurred at 3 months, participation in light exercises at 6 months, and consecutive jumping tests were conducted at the 12-month mark.

Evaluation Indicators

Patients were followed up every month for the first 3 months postoperatively. After this initial period, follow-ups were conducted every 3 months until the patients' function returned to normal. This follow-up protocol was maintained until February 2023. Magnetic resonance examination performed 1 year postoperatively to confirm tendon healing condition, anterior drawer test, Lachman test, pivot shift test performed, IKDC score,[10] Knee Injury and Osteoarthritis Outcome Score (KOOS) score,[11] Lysholm score[12] used to evaluate affected side knee joint function, AOFAS score[13] used to evaluate donor area ankle joint function. The Opti Knee three-dimensional motion measurement and analysis system-Yidong Medical Infrared Motion Gait Analyzer (Shanghai Yidong Medical Technology Co. Shanghai, China) was used for bilateral knee joint and ankle joint analysis collection. Data of inversion-eversion angle (IV-EV), internal and external rotation angle (IE-ET), flexion and extension angle (F-E), anterior and posterior displacement (A-P) of bilateral ankle joint & knee joint during normal walking, upper and lower displacement (U-L), and internal and external displacement (IT-ET), were obtained.

Statistical Methods

For analysis, the Statistical Package for Social Sciences IBM (SPSS-IBM), version 22 (SPSS Inc., Chicago, Illinois, USA), was employed. The data is displayed as the mean standard deviation. The Shapiro–Wilk test was performed to determine the normality of each group's data first, and it was discovered that the preoperative and postoperative ratings did not fit a normal distribution ($p < 0.1$). Then difference between the preoperative and postoperative group data normality test was performed, difference conformed to normal distribution ($p > 0.1$). Hence comparison of preoperative and postoperative group scores can be analyzed by paired t-test, test level $\alpha = 0.05$.

Results

Knee and Ankle Function and Complications

All 65 patients were followed up completely, follow-up time was 16–51 months, average 37.9 months. Wound healing was stage I in 63 patients, superficial infection occurred in tibial incision in two patients, infection controlled after anti-infection treatment, debridement & VSD suction. One patient presented with symptoms of common peroneal nerve injury, which were alleviated after symptomatic supportive treatment. Additionally, 15 patients experienced knee pain during rainy and cold weather. Six months and one year postoperatively patient's KOOS evaluation symptoms, pain, daily life activity ability, sports & entertainment ability, knee joint related quality of life score all significantly improved compared to preoperative scores, difference had statistical significance (Table 1). Knee joint function IKDC score, Lysholm score compared to preoperative had statistical difference but AOFAS ankle-foot score of donor area ankle joint had no statistical difference with preoperative (Table 2). Up to end of follow-up all patients had no severe knee joint pain, stiffness, joint cavity infection, Endobutton displacement or ligament rupture occurrence.

Postoperative Changes in Range of Motion of the Knee and Ankle

One year follow-up during normal gait full cycle/support phase/swing phase affected side knee joint inversion/eversion internal/external rotation internal/external displacement knee joint flexion angle superior/inferior displacement anterior/posterior displacement compared with healthy side difference all had no significant meaning. During normal gait full cycle/support phase/swing phase affected side ankle joint internal/external rotation internal/external displacement knee joint

Table 1 Comparison of knee KOOS scores before ACL reconstruction, 6 months postoperatively, and 12 months postoperatively.

KOOS Score	Preoperative ($N = 65$)	6 months postoperative ($N = 65$)	T-value	p-value[a]	12 months postoperative ($N = 65$)	T-value	p-value[b]
Symptoms (KOOS Pain)	58.4 ± 4.1	88.8 ± 6.4	−31.76	<0.001	90.8 ± 5.5	−37.92	<0.001
KOOS Pain	60.2 ± 5.9	90.3 ± 6.5	−27.53	<0.001	94.0 ± 5.9	−32.46	<0.001
Activities of daily living (KOOS ADL)	66.1 ± 3.0	93.7 ± 5.7	−34.03	<0.001	97.8 ± 4.3	−47.95	<0.001
Sport and recreational Ability (KOOS Sport/rec)	47.9 ± 6.4	71.1 ± 7.8	−18.43	<0.001	73.7 ± 6.2	−23.25	<0.001
Knee-related quality of life component (KOOS QOL)	53.0 ± 3.3	80.3 ± 9.2	−22.43	<0.001	83.9 ± 8.1	−28.24	<0.001

Abbreviations: ADL, Activities of daily living; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life component.; [a] Compare the 6-month postoperative to the preoperative.; [b] Compare the 12-month postoperative to 6-month postoperative.

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Table 2 Comparison of knee IKDC and Lysholm scores, and AOFAS ankle-hindfoot scores at preoperative, 6 months postoperative, and 12 months postoperative for ACL reconstruction.

Index	Preoperative	6 months postoperative	*T* value	*p*-value[a]	12 months postoperative	*T*-value	*p*-value[b]
Knee IKDC score	52.0 ± 9.4	90.1 ± 6.5	−26.61	<0.001	92.3 ± 4.8	−30.57	<0.001
Knee Lysholm score	50.1 ± 8.5	88.3 ± 5.9	−29.46	<0.001	91.5 ± 5.1	−33.35	<0.001
AOFAS Ankle-hindfoot score	97.3 ± 2.7	96.0 ± 4.7	1.95	=0.10	96.9 ± 4.1	0.63	=0.40

Abbreviations: ACL, anterior cruciate ligament; AOFAS, American Orthopedic Foot and Ankle Society; IKDC, International Knee Documentation Committee.; [a] Compare the 6-month postoperative to the preoperative.; [b] Compare the 12-month postoperative to 6-month postoperative.

Table 3 Comparison of the IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy knee joints at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T* Value	*p*-Value
IV-EV (°)	5.52 ± 0.34	5.42 ± 0.26	1.84	0.857
IT-ET (°)	12.61 ± 2.01	11.88 ± 2.21	1.97	0.714
F-E (°)	54.24 ± 3.32	55.12 ± 2.12	−1.80	0.069
A-P (mm)	2.22 ± 1.35	2.01 ± 1.22	0.93	0.079
U-L (mm)	4.45 ± 0.68	4.25 ± 0.58	1.80	0.151
IT-ET displacement (mm)	2.12 ± 0.58	2.08 ± 0.42	0.45	0.142

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

flexion angle superior/inferior displacement anterior/posterior displacement compared with healthy side difference all had no significant meaning (Tables 3–8). But during support phase affected side ankle joint inversion/eversion angle existed difference with healthy side (Healthy side [9.06 ± 0.34°] vs. Affected side [12.88 ± 0.62°]; $p = 0.017$, Table 7).

During follow-up, ankle angle differences between affected and unaffected sides show no significant impact on dorsiflexion due to PLT deficit. Compensatory actions by muscles like soleus and gastrocnemius were observed. One patient experienced superficial peroneal nerve inflammation, while two patients developed postoperative superficial infections, possibly linked to subcutaneous fluid accumulation.

Discussion

In this study, we found that the PLT can be used as an ideal graft replacement for the ACL of the knee. No significant difference in knee function was found in the treated side from the healthy side at 6 months and 1 year postoperatively, as shown in the similar IKDC scores, KOOS scores, Lysholm scores, and the AOFAS Ankle-hindfoot scores. However, increased ankle inversion activity in the donor area was found by three-dimensional gait analysis, suggesting that the grafting of the PLT leads to increased ankle inversion during the follow-up period. Due to the short follow-up period of this study, whether it leads to ankle instability in the long term needs to be further explored.

ACL Rupture and Graft Choice

ACL rupture not only impacts knee joint stability but also accelerates degeneration, common in sports like football and skiing. With an incidence rate of 68.6/100000, it's more prevalent in males (81.7/100000) than females (55.3/100000).[14] In the past two decades, knee joint reconstruction surgeries surged by 29 times.[15] The rise is attributed to sports development, transportation, and industrial growth. ACL treatment, based on factors like age and symptoms, mainly involves ligament reconstruction using materials like autologous tendons, allogeneic tendons, or artificial options.

Autologous tendon reconstruction is widely used in cross-ligament repair surgery to avoid potential rejection reactions from allogeneic tendons. Different substitutes have varying advantages. Autologous hamstring tendons (HTs) offer strength but may reduce knee flexion and muscle strength, potentially causing nerve injury. Autologous bone-patellar tendon-bone grafts promote quick healing but result in substantial trauma and lower strength than the original ACL, leading to complications. Other options like the iliotibial band, gracilis tendon, and tensor fasciae latae have distinct donor site complications, limiting their application.[16,17]

In recent years, autologous PLT has been widely used as a graft for ligament reconstruction in cases of ligament injuries. The PLT is harvested from the deep fascia of the calf and the upper portion of the fibula, extending to the outer lower side of the medial cuneiform and the base of the first metatarsal, with a length of approximately 22–28 cm.[18–20] The double-strand PLT

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Table 4 Comparison of the IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy knee joints during the support phase at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T*-value	*p*-Value
IV-EV (°)	3.88 ± 0.48	4.02 ± 0.46	−1.70	0.857
IT-ET (°)	10.22 ± 1.81	10.56 ± 2.14	−0.98	0.612
F-E (°)	49.56 ± 3.02	50.34 ± 2.66	−1.56	0.142
A-P (mm)	2.02 ± 1.22	2.21 ± 1.04	−0.96	0.068
U-L (mm)	4.00 ± 0.58	3.88 ± 0.46	1.31	0.182
IT-ET displacement (mm)	1.92 ± 0.78	2.12 ± 0.42	−1.82	0.164

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

Table 5 Comparison of the IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy knee joints during the swing phase at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T*-value	*p* value
IV-EV (°)	3.26 ± 0.16	3.35 ± 0.35	−1.89	0.857
IT-ET (°)	10.46 ± 2.32	11.08 ± 2.21	−1.56	0.714
F-E (°)	54.24 ± 3.32	55.22 ± 2.32	−1.95	0.069
A-P (mm)	2.22 ± 1.35	2.01 ± 1.22	0.93	0.079
U-L (mm)	4.45 ± 0.68	4.20 ± 0.38	1.96	0.151
IT-ET displacement (mm)	2.12 ± 0.58	2.08 ± 0.42	0.45	0.142

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

Table 6 Comparison of IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy ankle joints during the full cycle at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T*-value	*p* value
IV-EV (°)	10.51 ± 1.82	9.96 ± 1.68	1.79	0.087
IT-ET angle (°)	9.99 ± 1.02	10.29 ± 1.21	−1.53	0.165
F-E (°)	35.52 ± 3.86	36.54 ± 3.12	−1.66	0.245
A-P (mm)	2.03 ± 1.35	1.60 ± 1.22	1.91	0.082
U-L (mm)	0.39 ± 0.08	0.38 ± 0.12	0.56	0.220
IT-ET displacement (mm)	1.22 ± 0.58	1.08 ± 0.42	1.58	0.068

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

exhibits a tensile strength of about 2483 N and a stiffness of about 244 N/mm. Biomechanical studies have demonstrated that PLT possesses similar biomechanical properties to the cruciate ligaments. Its superficial location and ease of harvesting make it an ideal alternative for cruciate ligament reconstruction.[5,21,22]

PLT and Operative Techniques

The PLT has been successfully used for the reconstruction of the ACL or PCL alone. Various techniques exist for harvesting the PLT, including partial extraction (taking half), harvesting two-thirds, or procuring the entire tendon. When harvesting half of the PLT to achieve a diameter exceeding 8 mm, it often requires four overlapping strands. Harvesting two-thirds of the tendon proves to be comparatively challenging, with the residual portion tending to exhibit laxity.[19] The autologous semitendinosus tendon possesses good strength, but its diameter is uncertain. Harvesting this tendon may decrease knee joint flexion and internal rotation strength, potentially leading to sciatic nerve damage and decreased semitendinosus muscle strength-a crucial factor for certain athletes.[9] Biomechanical experiments have

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Table 7 Comparison of the IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy ankle joints during the support phase at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T*-value	*p* value
IV-EV (°)	12.88 ± 0.62	9.06 ± 0.34	43.56	0.017
IT-ET (°)	8.19 ± 1.44	8.74 ± 1.72	−1.98	0.260
F-E (°)	25.52 ± 3.35	26.36 ± 2.30	−1.67	0.120
A-P (mm)	1.62 ± 1.06	1.68 ± 1.22	−0.30	0.094
U-L (mm)	0.33 ± 0.22	0.34 ± 0.18	−0.28	0.120
IT-ET displacement (mm)	1.20 ± 0.48	1.02 ± 0.58	1.93	0.098

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

Table 8 Comparison of the IV-EV, IT-ET, F-E, A-P, U-L, IT-ET displacement of the femur relative to the tibia in the affected and healthy ankle joints during the swing phase at 12 months postoperatively.

Indicators	Affected side	Healthy side	*T*-value	*p* value
IV-EV (°)	6.08 ± 0.32	5.98 ± 0.46	1.44	0.087
IT-ET (°)	7.68 ± 1.15	8.04 ± 1.34	−1.64	0.164
F-E (°)	28.88 ± 3.66	27.76 ± 2.80	1.96	0.120
A-P (mm)	1.30 ± 1.21	1.42 ± 1.02	−0.61	0.084
U-L (mm)	0.36 ± 0.19	0.35 ± 0.24	0.26	0.065
IT-ET displacement (mm)	1.26 ± 0.26	1.16 ± 0.33	1.92	0.165

Abbreviations: A-P, anterior and posterior displacement; F-E, flexion and extension angle; IT-ET, internal and external rotation angle; IV-EV, Inversion-eversion angle; U-L, upper and lower displacement.

demonstrated that the ultimate tensile strength of double-strand PLT and double-strand HT is significantly higher than that of the natural ACL. The ultimate tensile strength of double-strand PLT is equivalent to that of four-strand HT. There were no significant differences in clinical and functional scores between preoperative and postoperative assessments. Saeed *et al.* found that HT autografts may lead to postoperative quadriceps weakness, while PLT autografts can provide athletes with better function within 6 months.[23] He *et al.*, through a meta-analysis, reached a similar conclusion, stating that the functional outcomes and graft survival rates of PLT autografts are comparable to those of HT autografts.[24] PLT is a suitable autograft alternative for knee joint reconstruction, helping to avoid the quadriceps-hamstring muscle imbalance that may occur with HT autografts. Our approach involves creating a longitudinal incision approximately 2–3 cm above and 1 cm behind the lateral malleolus of the affected limb, yielding a tendon length typically ranging from 24 to 27 cm. Following a three-strand overlap, the resultant length is approximately 8 cm, and the diameter generally measures 8–9 mm, rendering it stronger than a four-strand HT. The potential impact of disparate tendon harvesting methods on the ankle joint warrants further investigation.

In our approach, we utilized a single bundle multi-strand PLT with an average diameter of 8.2 mm and a length of 7.2 mm, ensuring adequate length and diameter. Besides diameter, precise surgical techniques are crucial. Careful identification of the PLT and differentiation from the peroneus brevis tendon is essential. After harvesting, the tendon ends are sutured to preserve partial functionality. The harvested tendon should be woven into a cylindrical shape to ensure even force distribution. Minimizing the use of sutures in the joint cavity during weaving helps reduce irritation to the synovium. Preservation of the residual ACL during joint cavity cleaning retains partial proprioception and minimizes joint fluid entry into the bone tunnel, promoting tendon-bone healing. Proper placement of the bone tunnels is critical; deviation in the position may lead to graft impingement or joint instability. We utilized the femoral bone tunnel positioning method through the tibial bone tunnel, ensuring exposure of the anatomical endpoints of the ACL. The diameter of the bone tunnel should match the diameter of the graft to prevent the occurrence of the "bungee effect" and "windshield wiper effect". To minimize the risk of tendon laxity, the woven tendon is pre-tensioned before implantation. Post-implantation, the graft is tensioned by repetitively flexing the knee 4–5 times before screw fixation.

Effectiveness of PLT in ACL Reconstruction

In a study by Goyal and colleagues,[8] they performed ACL reconstruction using the ipsilateral Peroneus Longus

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autograft in cases of ACL and multiligament injury repair. They found that all patients' ankle dorsiflexion ($p = 0.32$), plantar flexion ($p = 0.19$), eversion strength ($p = 0.6$), first ray plantar flexion strength ($p = 0.52$), and AOFAS score ($p = 0.29$) were not significantly different compared to the normal side. Therefore, they concluded that for multi-ligament knee injury and ACL repair reconstruction, the Peroneus Longus autograft can be considered as a potential autograft choice. These results[8] indicate that the use of the PLT for ACL reconstruction is effective and has little impact on ankle joint function.

Postoperative Outcomes Analysis

In this study, the comparison of postoperative outcomes at 12 months revealed several findings (Tables 3–8). In the affected knee joints, no significant differences were observed in IV-EV, IT-ET, F-E, as well as anterior and posterior, upper and lower, and IT-ET displacement of the femur relative to the tibia during the swing phase, when compared to healthy knee joints ($p > 0.05$). Similarly, in the affected ankle joints during the full cycle, there were no significant disparities in these parameters compared to the healthy side ($p > 0.05$). However, during the support phase, the affected ankle joints exhibited a significantly higher IV-EV compared to the healthy side ($p = 0.017$), although there were no significant differences in other displacement and rotation angles. Furthermore, during the swing phase, no significant differences were found between affected and healthy ankle joints in various measured parameters ($p > 0.05$). These results provide valuable insights into the postoperative stability and functionality of the knee and ankle joints, suggesting overall positive outcomes in the evaluated parameters at the 12-month follow-up. This suggests an increase in inversion-eversion motion in the operated foot during the support phase. However, despite this change in range of motion, subjective function ratings for the operated and non-operated feet are similar. This could be attributed to two factors. Firstly, the AOFAS Ankle-hindfoot score, used for subjective functional assessment, has inherent subjectivity and a larger margin of error, making it less precise in capturing subtle changes in ankle joint motion. Secondly, the relatively small variation in IV-EVs at the ankle may not be substantial enough for patients to perceive a meaningful alteration in ankle joint function.

Assessment of Ligament Reconstruction and Complications

During follow-up, magnetic resonance imaging was used to evaluate the reconstructed ligament, showing uniform and continuous signals. The internal fixation position was satisfactory, with no instances of re-rupture. However, among the 65 patients, 15 experienced knee pain during rainy and cold weather, likely due to synovitis caused by cartilage, meniscus injury, or residual suture from the transplant.

The PLT is indeed a crucial component in maintaining foot arch morphology and assisting in body balance. It's used as an autograft in ligament reconstruction, particularly for the ACL or PCL reconstruction.[8,25] However, concerns have been raised about potential complications at the donor site. A study by Angthong *et al.* revealed that there could be a significant reduction in the peak torque of inversion and eversion after harvesting the PLT graft.[7] In the study by Bi *et al.*, the mean preoperative IKDC, Lysholm, and Tegner scores(52.0 ± 8.27, 50.9 ± 8.50, and 1.8 ± 0.87, respectively) increase significantly to 94.2 ± 2.61, 95.2 ± 2.64, and 6.8 ± 1.50, respectively at the final average 40-month follow-up ($p < 0.001$ for all).[25] In this study, the preoperative IKDC and Lysholm scores (52.0 ± 9.4, 50.1 ± 8.5 respectively) increased to 92.3 ± 4.8, 91.5 ± 5.1 respectively at the 12-month follow up with significant differences ($p < 0.001$), which is consistent with the previous study.[25] However, it's important to note that a slight decrease in the AOFAS score (postoperative 96.9 ± 4.1 vs. preoperative 97.3 ± 2.7, $p = 0.40$) at the last post-operative follow-up for patients with PLT autograft compared with pre-operative scores. This indicates that there might be a slight impact on the donor ankle joint function, which should be considered during surgical planning.

Optimization of PLT Harvesting

Researches have shown satisfactory results using half of the PLT as a graft.[24–26] However, during the surgical procedure, the author observed significant individual differences in the PLT. After weaving half of the PLT, the diameter is relatively small, making it difficult to apply to all patients. In addition, obtaining half of the PLT can be relatively challenging and may lead to proximal PLT rupture during the tendon harvesting process. Moreover, the process of harvesting the half tendon can lead to proximal PLT ruptures. Research conducted by Spragg and colleagues involving 491 ACL reconstruction patients revealed that when the diameter of the transplanted tendon is between 7 and 9 mm, for every 0.5 mm increase in diameter, the likelihood of revision surgery decreases by 0.82 times.[27] Similarly, a follow-up study involving 263 patients by Mariscalco and colleagues[28] found a positive correlation between postoperative knee joint scores (IKDC and KOOS) and the diameter of the transplant when the diameter is below 8 mm. These findings highlight the significance of the transplant diameter in surgical outcomes.

Utilization of Advanced Measurement Systems

The Opti_Knee three-dimensional motion measurement and analysis system- Yidong Medical Infrared Motion Gait Analyzer used in this study, which accurately measures six degrees of freedom data during motion. By combining subjective evaluations and three-dimensional gait analysis, our study demonstrated stable knee joint function post-reconstruction. During normal gait, the six joint movements in the knee were comparable to those of the healthy knee. The postoperative AOFAS score for the donor ankle joint reached 96.9, indicating patient satisfaction. However, an increase in internal and external inversion was observed during support, indicating some impact on the donor ankle joint function. Although compensatory mechanisms involving the

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peroneus brevis tendon, posterior tibial tendon, and adjacent muscles were observed,[13] there was still a significant effect on the donor ankle joint's internal and external inversion, emphasizing the need for further strengthening of ankle joint function through exercises.

In this study, a combination of subjective assessments and three-dimensional gait analysis during a 1-year postoperative follow-up revealed no statistically significant differences in knee joint mobility during the full gait cycle, stance phase, and swing phase compared to the unaffected side. This suggests that autograft PLT reconstruction for ACL can achieve consistent knee joint function postoperatively. Further investigation into ankle joint mobility data during the support phase uncovered differences in IV-EVs between the affected and unaffected sides. Post PLT transplantation, increased IV-EVs indicated that the short-term compensatory function of the peroneus brevis tendon may be insufficient for ankle eversion. Whether ankle IV-EV changes can be improved with ankle muscle exercises or extended follow-up time requires further research.

Complications and Rehabilitation Strategies

During follow-up, statistical differences in ankle dorsiflexion and plantarflexion angles between the affected and unaffected sides were not observed, suggesting that the deficit of the PLT has no significant impact on ankle dorsiflexion. This may be attributed to compensatory actions by muscles such as the soleus, gastrocnemius, posterior tibialis, and peroneus brevis. One patient experienced symptoms of superficial peroneal nerve inflammation during follow-up. The symptoms gradually diminished and disappeared after 3 months with oral cobamamide and physical therapy. This complication may be related to blunt trauma during tendon harvesting. Therefore, attention should be paid to the proximal distance of the tendon harvesting instrument from the fibular head, not less than 4–5 cm.

Two patients developed superficial infections at the tibial incision site postoperatively, potentially related to subcutaneous fluid accumulation due to bleeding at the bone tunnel. Placing a drainage tube below the tibial incision postoperatively may reduce the risk of skin infection.

Although all patients universally comply with a standardized rehabilitation regimen, involving knee compression, ankle exercises, and progressive weight-bearing, the effectiveness of rehabilitation may be influenced by individual differences and compliance. Hence, the implementation of personalized plans, routine progress assessments, and the delivery of patient education and psychological support becomes imperative. The utilization of such a comprehensive rehabilitation strategy has the potential to improve postoperative recovery outcomes.

Limitations and Prospects

This study recognizes limitations that impact its depth and clinical implications. The absence of secondary surgical exploration hinders understanding the cause and extent of peroneal nerve neuritis. The treatment's universal applicability remains uncertain despite success in one case. Inadequate understanding of the tendon harvesting instrument's impact necessitates improved surgical techniques. The short average follow-up time of 37.9 months and limited cases constrain the study's depth and generalizability, urging extended follow-up and larger samples. The infrared motion analysis system introduces potential errors, emphasizing the need for refined methodologies. Exclusive focus on PLT without comparing grafts limits establishing PLT's superiority, especially regarding foot arch dynamics. Future research aims to address these constraints through detailed comparative analyses, providing a more comprehensive understanding of peroneal nerve neuritis and ACL reconstruction outcomes, considering foot arch dynamics. Overcoming these limitations is crucial for advancing clinical knowledge and enhancing patient care.

Conclusion

The use of the PLT for ACL reconstruction is associated with satisfactory knee joint function. Nevertheless, it does affect ankle joint inversion and eversion, necessitating postoperative exercises for enhanced ankle function. Similar subjective function ratings for both operated and non-operated feet, despite increased inversion-eversion motion in the operated foot, may be influenced by the subjective nature and margin of error in the AOFAS Ankle-hindfoot score, as well as the relatively small variation in ankle angles.

Author Contributions

Zhe Ge, Shichao Zhang performed the study design, literature review, drafted the manuscript; Zhe Ge, Shichao Zhang, Yingkai Zhang, Xianwei He and Guoping Cai performed the data collection, patient follow-up, data analysis, and the manuscript revisions. All authors read and approved the final manuscript.

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Conflict of Interest Statement

All named authors have no conflicts of interests related to this study.

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References

1. Markatos K, Kaseta MK, Lallos SN, Korres DS, Efstathopoulos N. The anatomy of the ACL and its importance in ACL reconstruction. Eur J Orthop Surg Traumatol. 2013;23(7):747–52.

2. Fleming JD, Ritzmann R, Centner C. Effect of an anterior cruciate ligament rupture on knee proprioception within 2 years after conservative and operative treatment: a systematic review with meta-analysis. Sports Med. 2022;52(5):1091–102.

3. Jenkins SM, Guzman A, Gardner BB, Bryant SA, Del Sol SR, McGahan P, et al. Rehabilitation after anterior cruciate ligament injury: review of current literature and recommendations. Curr Rev Musculoskelet Med. 2022;15(3):170–9.

4. Zheng SF, Huang HY, Zhang Y, Yin QS, Ding HW. Comparison of selection and efficacy of arthroscopic anterior cruciate ligament grafts for reconstruction. Chinese J Bone and Joint Injury. 2009;24(7):592–4.

5. Wiradiputra AE, Febyan AG. Peroneus longus tendon graft for anterior cruciate ligament reconstruction: a case report and review of literature. Int J Surg Case Rep. 2021;83:106028.

6. Rhatomy S, Hartoko L, Setyawan R, Soekarno NR, Zainal Asikin AI, Pridianto D, et al. Single bundle ACL reconstruction with peroneus longus tendon graft: 2-years follow-up. J Clin Orthop Trauma. 2020;11(suppl 3):S332–6.

7. Angthong C, Chernchujit B, Apivatgaroon A, Chaijenkit K, Nualon P, Suchao-in K. The anterior cruciate ligament reconstruction with the peroneus longus tendon: a biomechanical and clinical evaluation of the donor ankle morbidity. J Med Assoc Thai. 2015;98(6):555–60.

8. Goyal T, Paul S, Choudhury AK, Sethy SS. Full-thickness peroneus longus tendon autograft for anterior cruciate reconstruction in multi-ligament injury and revision cases: outcomes and donor site morbidity. Eur J Orthop Surg Traumatol. 2023;33:21–7.

9. Shi FD, Hess DE, Zuo JZ, Liu SJ, Wang XC, Zhang Y, et al. Peroneus longus tendon autograft is a safe and effective alternative for anterior cruciate ligament reconstruction. J Knee Surg. 2019;32(8):804–11.

10. Kunze KN, Palhares G, Uppstrom TJ, Hinkley P, Rizy M, Gomoll AH, et al. Establishing minimal detectable change thresholds for the international knee documentation committee and Kujala scores at one and two years after patellofemoral joint arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2023;31:3299–306.

11. Collins NJ, Prinsen CA, Christensen R, Bartels EM, Terwee CB, Roos EM. Knee injury and osteoarthritis outcome score (KOOS): systematic review and meta-analysis of measurement properties. Osteoarthr Cartil. 2016;24(8):1317–29.

12. Natali S, Screpis D, Patania E, De Berardinis L, Benoni A, Piovan G, et al. Efficacy and long-term outcomes of intra-articular autologous micro-fragmented adipose tissue in individuals with Glenohumeral osteoarthritis: a 36-month follow-up study. J Pers Med. 2023;13(9):1309.

13. Van Lieshout EM, De Boer AS, Meuffels DE, Den Hoed PT, Van der Vlies CH, Tuinebreijer WE, et al. American Orthopaedic Foot and Ankle Society (AOFAS) ankle-Hindfoot score: a study protocol for the translation and validation of the Dutch language version. BMJ Open. 2017;7(2):e012884.

14. Sanders TL, Maradit KH, Bryan AJ, Larson DR, Dahm DL, Levy BA, et al. Incidence of anterior cruciate ligament tears and reconstruction: a 21-year population-based study. Am J Sports Med. 2016;44(6):1502–7.

15. Nogaro MC, Abram S, Alvand A, Bottomley N, Jackson WFM, Price A. Paediatric and adolescent anterior cruciate ligament reconstruction surgery. Bone Joint J. 2020;102-B(2):239–45.

16. Mouarbes D, Menetrey J, Marot V, Courtot L, Berard E, Cavaignac E. Anterior cruciate ligament reconstruction: a systematic review and meta-analysis of outcomes for quadriceps tendon autograft versus bone-patellar tendon-bone and hamstring-tendon autografts. Am J Sports Med. 2019;47(14):3531–40.

17. Lin KM, Boyle C, Marom N, Marx RG. Graft selection in anterior cruciate ligament reconstruction. Sports Med Arthrosc Rev. 2020;28(2):41–8.

18. Keyhani S, Qoreishi M, Mousavi M, Ronaghi H, Soleymanha M. Peroneus longus tendon autograft versus hamstring tendon autograft in anterior cruciate ligament reconstruction: a comparative study with a mean follow-up of two years. Arch Bone Jt Surg. 2022;10(8):695–701.

19. Agarwal A, Singh S, Singh A, Tewari P. Comparison of functional outcomes of an anterior cruciate ligament (ACL) reconstruction using a peroneus longus graft as an alternative to the hamstring tendon graft. Cureus. 2023;15(4):e37273.

20. Butt UM, Khan ZA, Amin A, Shah IA, Iqbal J, Khan Z. Peroneus longus tendon harvesting for anterior cruciate ligament reconstruction. JBJS Essent Surg Tech. 2022;12(2):e20.00053.

21. Pearsall AT, Hollis JM, Russell GJ, Scheer ZA. A biomechanical comparison of three lower extremity tendons for ligamentous reconstruction about the knee. Art Ther. 2003;19(10):1091–6.

22. Du TS, Zhang CL. Current status of development of autologous peroneal longissimus tendon graft for reconstruction of anterior cruciate ligament. Chinese J Joint Surgery (Electronic Edition). 2015;9(3):412–5.

23. Saeed UB, Ramzan A, Anwar M, Tariq H, Tariq H, Yasin A, et al. Earlier return to sports, reduced donor-site morbidity with doubled peroneus longus versus quadrupled hamstring tendon autograft in ACL reconstruction. JB JS Open Access. 2023;8(4):e23.00051.

24. He J, Tang Q, Ernst S, Linde MA, Smolinski P, Wu S, et al. Peroneus longus tendon autograft has functional outcomes comparable to hamstring tendon autograft for anterior cruciate ligament reconstruction: a systematic review and meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2021;29(9):2869–79.

25. Bi M, Zhao C, Zhang Q, Cao L, Chen X, Kong M, et al. All-inside anterior cruciate ligament reconstruction using an anterior half of the peroneus longus tendon autograft. Orthop J Sports Med. 2021;9(6):1813038650.

26. de Oliveira DE, Horita MM, de Oliveira E, Silva M, Salas VER, Jorge PB. Anterior half of the peroneus longus tendon combined with semitendinosus and Gracilis tendons for anterior cruciate ligament reconstruction: an athlete case report. Case Rep Orthop. 2021;2021:9978383.

27. Spragg L, Chen J, Mirzayan R, Love R, Maletis G. The effect of autologous hamstring graft diameter on the likelihood for revision of anterior cruciate ligament reconstruction. Am J Sports Med. 2016;44(6):1475–81.

28. Mariscalco MW, Flanigan DC, Mitchell J, Pedroza AD, Jones MH, Andrish JT, et al. The influence of hamstring autograft size on patient-reported outcomes and risk of revision after anterior cruciate ligament reconstruction: a multicenter Orthopaedic outcomes network (MOON) cohort study. Art Ther. 2013;29(12):1948–53.

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