BMC Surgery

RESEARCH Open Access

Comparative efficacy of different lengths of anterior cruciate ligament stump during reconstruction with peroneus longus tendon

Chunrong Chen[1], Zhang Jing[2], Zhimin Li[3], Minghua Hu[4], Chaoyong Bei[1] and Linwei Xin[4*]

Abstract

Background Anterior cruciate ligament (ACL) injury affects individuals, and successful ACL helps patients return to an active lifestyle. This study compared the clinical effects of two treatment schemes of retention length ≥ 1/2 and < 1/2 of ACL stump in patients under reconstruction with peroneus longus tendon (PLT).

Methods A total of 34 patients with ACL injury of knee joint treated by unilateral ACL reconstruction with PLT were recruited in this study. They were divided into N1 (retention length of ACL stump ≥ 1/2) and N2 (retention length of ACL stump < 1/2) groups ($n = 17$ in each group). The knee joint proprioceptive threshold of passive motor perception was used to evaluate recovery of proprioception. The international knee documentation committee (IKDC) score, Lysholm score, and Tegner activity score (TAS) were used to evaluate knee joint functions. Lachman test, anterior drawer test (ADT), and pivot shift test (PST) were used to evaluate the stability of knee joint. Single-legged hop test and return-to-sport ratio were used to evaluate the movement ability.

Results In 6th month and 12th month after operation, the passive motor perception threshold in N1 group was better than than that in N2 group ($p < 0.05$). In 12th month after the operation, the return-to-sport ratio in N1 group was increased compared to the N2 group ($p < 0.05$). There were no significant differences in results of IKDC score, Lysholm score, TAS, Lachman test, ADT, or PST between the two groups in 6th month and 12th month after the operation ($p > 0.05$). In addition, no significant difference was found in the single-legged hop test between the two groups in the 12th month after operation ($p > 0.05$).

Conclusion During ACL reconstruction with PLT, treatment strategy of ACL stump retention length ≥ 1/2 is more effective than treatment strategy of length < 1/2 for patients with ACL injury of the knee joint.

Keywords Anterior cruciate ligament, Retention length, Reconstruction, Peroneus longus tendon

*Correspondence:
Linwei Xin
xinlinwei999888@163.com
[1]Department of Limb Trauma and Hand Surgery, Affiliated Hospital of Guilin Medical University, No.15 Lequn Road, Xiufeng District, Guilin City, Guangxi Zhuang Autonomous Region 541001, China
[2]Clinical Teaching and Training Center, Affiliated Hospital of Guilin Medical University, No.15 Lequn Road, Xiufeng District, Guilin City, Guangxi Zhuang Autonomous Region 541001, China
[3]Department of Spinal Bone Surgery, Affiliated Hospital of Guilin Medical University, No.15 Lequn Road, Xiufeng District, Guilin City, Guangxi Zhuang Autonomous Region 541001, China
[4]Orthopaedics Department, The Second Affiliated Hospital of Guilin Medical University, No. 212 Renmin Road, Lingui District, Guilin City, Guangxi Zhuang Autonomous Region 541199, China

Introduction

Anterior cruciate ligament (ACL) injury is one of the common clinical diseases, and the number of patients with ACL injury is more than 10 million every year in China [1]. ACL injury can occur in many cases, and its pathogenesis is complex. As an important joint in the body, the knee joint has the characteristics of a complex structure and large volume, and it mainly carries out the related activities of stability with the help of the surrounding ligaments represented by the ACL [2]. ACL injury and fracture will seriously affect the stability of knee joint activity and then produce a variety of complications such as pain, meniscus injury, and articular cartilage degeneration, thus affecting the quality of life of patients [3]. Arthroscopic ACL reconstruction with autologous graft is the current mainstream treatment for ACL injury with the advantages of a small wound, safe operation, convenience, fast recovery, and good recovery of knee joint function [4]. However, there is still a high failure rate [5].

Nowadays, the issue of stump preservation during ACL reconstruction is a hot topic in orthopedic research. The proprioceptive injury caused by ACL injury and subsequently changed neuromuscular functions are considered to be the main factors affecting knee joint function instability [6]. Many clinicians believe that the preservation of the stump during ACL reconstruction can increase the proprioceptive function of the regenerative mechanical receptors around the graft, promote the healing process of the graft, and improve postoperative knee function [7, 8]. With the deepening of the research, some scholars support that retaining more length of the stump in ACL reconstruction can obtain more satisfactory results [9–12]. Several studies found that the prognosis of patients with a stump length greater than 20% during ACL reconstruction is more satisfactory, and the patient's treatment effect and proprioception recovery are better [9–11]. It is also shown that the different position of human ACL stump has different differentiation abilities. The distal third of the ACL stump (near the tibial end) tends to differentiate into cartilage, and the middle third of the ACL stump has a strong tendency to differentiate into osteoblasts and ligaments [12]. Based on our clinical work, we retrospectively reviewed the length of the retained residual end and attempted to compare it with a residual end length of 1/2 as the entry point.

Although the preservation of the stump during ACL reconstruction has attracted more and more scholars' attention, there is still little research evidence on the effect of different stump lengths on clinical outcomes. In addition, the lack of uniform standards and standardized treatment modes is an urgent problem in clinics. This study is a retrospective study, and selecting peroneus longus tendon (PLT) as the graft is a routine work in our reconstruction. PLT has become an ideal autograft for ACL reconstruction surgery due to its sufficient length, elasticity, and distance from the knee joint [13–16]. Therefore, this study aimed to compare the clinical effects of two treatment schemes of retention length of ACL stump ≥ 1/2 and < 1/2 in reconstruction with PLT.

Patients and methods

Patients

This retrospective study was approved by the Ethics Committee of the Affiliated Hospital of Guilin Medical University, China (No. 2021TDXLYJSLL-10). All patients provided written informed consent for participation in the study. From January 2017 to December 2020, 34 patients with ACL injury of the knee joint who were treated by arthroscopic ACL reconstruction with PLT in the Affiliated Hospital of Guilin Medical College were recruited in this study. They were divided into N1 group (length ≥ 1/2) and N2 (length < 1/2) group according to the stump retention length ($n = 17$ in each group). The characteristic clinical data of patients in the two groups were collected, including age, gender, body mass index (BMI), time from onset to operation, affected side of the knee (left/right), meniscus injury, operation time, amount of operative bleeding, hospitalization day and magnetic resonance imaging (MRI) images.

Inclusion criteria: (1) patients who underwent one-stage unilateral ACL reconstruction with PLT as an autologous graft; (2) patients without other ligament injury; (3) patients with a clear history of trauma; (4) patients with unilateral ACL injury without contralateral knee injury; (5) patients with positive signs in clinically physical examination in the preoperative period, anterior drawer test (ADT), pivot shift test (PST) and Lachman test; and (6) patients with complete clinical data and 12 months of follow-up.

Exclusion criteria: (1) patients with loss of meniscus tension after resection of the edge around the meniscus; (2) patients with cartilage lesions higher than grade II according to the Outerbridge classification system under arthroscopy; (3) patients with a history of previous knee surgery; (4) patients with a certain degree of injury to the contralateral knee joint; and (5) patients with incomplete clinical records.

Operation methods

The operation process under arthroscopy was shown in Fig. 1. The patient who recieved spinal anesthesia took a supine position on the operating table. The tourniquet was placed at the root of the thigh of the affected limb of patient. The anteromedial and lateral approaches of the patella were performed, and the arthroscopy was placed through the surgical channel. An incision was made at 1 cm posterior and 2 cm above the lateral malleolus of the

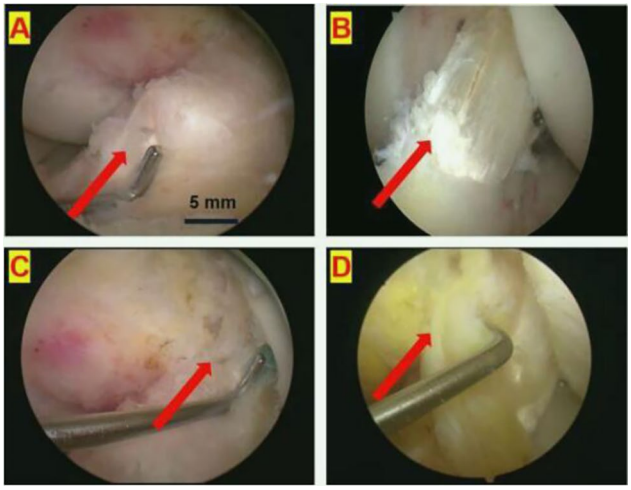

Fig. 1 The visual field of endoscopic surgery in the two groups. (**A**) An arthroscopic probe (tail end 5 mm) was used to measure the length of the stump and ligament; (**B**) Reserving 1/2 of the length of the reconstructed ligament; (**C**) The lengths of the stump and ligament were measured by the arthroscopic probe (tail end 5 mm) (**D**) Remnant > 1/2 reconstructed ligament length. The scale is 5 mm

affected limb, and the peroneus longus was removed with the help of a tendon taker [17]. The center was positioned in the single-bundle isometric reconstruction area of the femur. The femoral tunnel was prepared and the line was crossed for standby. ACL positioning was performed at the intersection of the lateral meniscus extension line and the intercondylar eminence to prepare the tibial tunnel [18, 19]. The graft was introduced into the corresponding bone tunnel. The femoral side of the graft was fixed with an Endobutton plate. After flipping the Endobutton plate, the knee joint flexion and extension activities were pre-stretched for 20 times. Fixation and screwing at 30° of knee flexion were performed in each patient using absorbable compression screws (specification model 72201776 from Xerox, with a length of 25 mm and a diameter of 9 mm) to fix the graft. Under the condition of 90° flexion of the knee joint, the length from the residual tissue and the distal end (tibial side) of the reconstructed ligament to the proximal end was measured with a 5 mm probe under arthroscopic monitoring, which was used for calculation of residual tissue and reconstructed ligaments [20]. When lengths were between 5 mm, a 1.0 mm Kirschner wire was used for further comparison. Each measurement was repeated for 3 times and the average was taken to minimize bias as much as possible.

Postoperative treatment and rehabilitation

Ice compress was performed after the operation. The bandages were fixed by compression bandage and the plasma drainage tube was removed at 24 h to 48 h after operation. In the first week after the operation, the rehabilitation physician pushed the patella to relax the knee joint and passively flexed the knee to 30°. The rehabilitation physician passively flexed the knee to 60° in the second week. After 2 weeks, the knee extension and flexion training and ankle joint function exercises were performed under the guidance of the rehabilitation division to restore the normal activities of the knee joint and ankle joint. At 4 and 6 weeks after operation, 90° and 135° movements were allowed, respectively. Knee braces were removed at 12 weeks after the operation. Straight running and change of running direction were allowed at 3 months and 6 months after operation, respectively. Patients in the two groups were followed up in the 6th month and 12th month after the operation by the following assessments.

Proprioceptive threshold of passive motor perception

The patient's hearing and vision were separated with eye masks and ear masks, respectively. The patient's affected limb was placed on a continuous passive motion (CPM). When the initial angle was adjusted from 30°, the CPM would move slowly to the extension direction at a speed of 0.5°/s. During the movement, when the patient perceived the first change in the angle of knee joint activity, the measured angle was recorded. In the measurement process, the change of knee joint perception angle was measured by angle calculation. The initial knee joint angle would be repeated for 3 times, and the average time was taken. Finally, 0.5°/s × average time (s) was used as the proprioceptive threshold of passive motor perception [21, 22].

Knee joint function score

The International Knee Documentation Committee (IKDC) score, Lysholm score, and Tegner activity score (TAS) were used to evaluate knee joint functions. The higher the IKDC score, the lighter the symptoms and signs [23]. The Lysholm score focused on the evaluation of knee joint function after a knee ligament injury, including claudication, pain, swelling, and other items [24, 25]. TAS was often used to evaluate the function of the knee after ACL reconstruction [26].

Knee stability test

Lachman test, anterior drawer test (ADT), and pivot shift test (PST) were used to evaluate the stability of knee as previously described [20, 27, 28]. Both the ADT and Lachman tests were conducted by personnel responsible for preoperative evaluation and recording. Each measurement was completed by 2 individuals in the team, excluding the surgeon, with one person conducting the test while the other measured. The measurements were then alternated and averaged 6 times. The PST was conducted by 3 persons, and the result of the majority of persons was taken as the final result.

Table 1 Comparison of general clinical data between the two groups

Items	N1 group (*n* = 17)	N2 group (*n* = 17)	t/χ^2/z	*p*
Gender (male/female)	11/6	10/7	0.125	0.724
Age (years)	32.29 ± 14.94	30.41 ± 11.19	0.417	0.680
BMI	24.04 ± 3.88	23.89 ± 7.39	0.103	0.918
Time from onset to operation (weeks)	9.14(2.5,13.5)	3.85(1.93,9.29)	-1.17	0.245
Affected side of the knee (left/right)	11/6	11/6	0	1
Meniscus injury	9/8	8/9	0.118	0.732
Operation time (min)	98.94 ± 31.67	97.47 ± 30.04	0.139	0.890
Amount of operative bleeding (mL)	30.88 ± 11.21	30.59 ± 15.50	0.063	0.950
Hospitalization day (days)	6.53 ± 1.70	6.53 ± 1.70	-1.291	0.206

BMI, body mass index

Knee joint movement ability test

Single-legged hop test and return-to-sport ratio were used to evaluate the movement ability of knee joint. The hop test was performed as follows: the patient was asked to stand on one foot with the examined limb and jumped as much as possible, in which the take-off and landing were on the same side of the limb. The distance was measured, and the ratio of the jump distance of the affected limb to the jump distance of the contralateral limb was compared [20]. TAS was used to evaluate the recovery of complete return of movement in patients after ACL reconstruction, that is, whether TAS within 2 years after ACL reconstruction can reach the level before ACL injury. If achieved, it is considered that patients have completed the movement ability as before injury and can return to exercise [29].

Postoperative complications

Postoperative complications such as joint cavity infection, venous thrombosis, nerve injury, and graft failure were observed during the 12-month follow-up period.

Statistical analysis

The statistical analysis was carried out by Statistical Package for the Social Sciences (SPSS) 26.0 software (SPSS Inc., Chicago, IL, USA). The normal distribution data were expressed as means ± standard deviation (SD) and compared by *t*-test or Mann-Whitney U (MWU) test. Non-normal distribution data were described by M (P25, P75) and compared by non-parametric test. χ^2 test was used to compare the counting data between the two groups. When *p* was less than 0.05, the difference was statistically significant.

Table 2 Comparison of the proprioceptive threshold of knee join between the two groups

Items	N1 group (*n* = 17)	N2 group (*n* = 17)	t	*p*
Before operation	2.65 ± 0.16	2.58 ± 0.15	0.125	0.239
In the 6th month after the operation	1.34 ± 0.13*	1.64 ± 0.71*	0.417	< 0.001
In the 12th month after the operation	1.13 ± 0.11*△	1.37 ± 0.78*△	0.103	< 0.001
F	631.175	615.243		
p	< 0.001	< 0.001		

*$p < 0.05$ compared with that before operation; △ $p < 0.05$ compared with that in the 6th month after operation

Results

Comparison of general clinical data between the two groups

General clinical data including age, gender, BMI, time from onset to operation, affected side of the knee (left/right), meniscus injury, operation time, amount of operative bleeding, hospitalization day in the two groups were collected and compared (Table 1). There were 11 males and 6 females in the N1 group with an average age of 32.29 ± 14.94 years old, and there were 10 males and 7 females in the N2 group with an average age of 30.41 ± 11.19 years old ($P > 0.05$). The time from onset to operation was 9.14 weeks (2.5,13.5) and 3.85 weeks (1.93,9.29) in N1 and N2 groups, respectively ($P = 0.245$). The operation time was 98.94 ± 31.67 min and 97.47 ± 30.04 min in the N1 and N2 groups, respectively ($P = 0.890$). The amount of operative bleeding was 30.88 ± 11.21 mL and 30.59 ± 15.50 mL in the N1 and N2 groups, respectively ($P = 0.950$). The hospitalization day was 6.53 ± 1.70 days and 7.24 ± 1.48 days in the N1 and N2 groups, respectively ($P = 0.206$). In addition, there were no significant differences in BMI, the affected side of the knee (left/right), and meniscus injury between the two groups ($P > 0.05$).

Comparison of the proprioceptive threshold of passive motor perception of knee join between the two groups

The proprioceptive threshold of passive motor perceptionof knee join between the two groups was evaluated, as shown in Table 2. Before the operation, there was no significant difference in the passive motor perception threshold of knee join between the two groups ($P = 0.239$). In the 6th month and 12th month after the operation, the passive motor perception threshold of the knee joint in the N2 group was both increased in comparison with those in the N1 group ($P < 0.05$). Moreover, in the 6th month and 12th month after the operation, the passive motor perception threshold of the knee joint in the two groups was improved significantly, compared to that before the operation ($P < 0.05$).

Comparison analysis of preoperative and postoperative IKDC scores, Lysholm score, and TAS between the two groups

Preoperative and postoperative IKDC scores, Lysholm score, and TAS were analyzed and compared between the two groups (Table 3). Before the operation, there were no significant differences in the IKDC score, Lysholm score, and TAS between the two groups ($P>0.05$). In the 6th month and 12th month after the operation, the IKDC score, Lysholm score, and TAS in the two groups were higher than those before the operation ($P<0.05$). However, in the 6th month and 12th month after the operation, the IKDC score, Lysholm score, and TAS in the N2 group were all not changed significantly in comparison with those in the N1 group ($P>0.05$).

Table 3 Comparison analysis of preoperative and postoperative IKDC scores, Lysholm score, and TAS between the two groups

Items		N1 group ($n=17$)	N2 group ($n=17$)	t	*p*
IKDC scores	Before operation	68.12 ± 7.79	67.35 ± 5.93	0.322	0.749
	In the 6th month after the operation	86.12 ± 3.06*	84.59 ± 2.694*	1.547	0.132
	In the 12th month after the operation	91.24 ± 2.08*△	92 ± 2.85*△	0.894	0.378
	F	101.219	161.44		
	p	< 0.001	< 0.001		
Lysholm score	Before operation	64.95 ± 9.59	66.00 ± 6.71	-0.373	0.712
	In the 6th month after the operation	84.88 ± 3.10*	83.00 ± 3.66*	1.619	0.115
	In the 12th month after the operation	92.00 ± 2.35*△	91.00 ± 2.03*△	1.329	0.193
	F	96.629	133.008		
	p	< 0.001	< 0.001		
TAS	Before operation	2.71 ± 1.11	2.88 ± 0.93	-0.504	0.617
	In the 6th month after the operation	5.71 ± 0.69*	5.24 ± 0.90*	1.170	0.097
	In the 12th month after the operation	7.12 ± 1.05*△	7.00 ± 0.71*△	0.382	0.705
	F	92.409	100		
	p	< 0.001	< 0.001		

*$p<0.05$ compared with that before operation; △ $p<0.05$ compared with that in the 6th month after operation

Comparison of knee joint stability between the two groups

Knee joint stability between the two groups in terms of the Lachman score, ADT score, and PST score were compared between the two groups (Table 4). It was suggested that, before the operation, there were no significant differences in the Lachman score, ADT score, and PST score between the two groups ($P>0.05$). After the operation of 6 months and 12 months, the Lachman score, ADT score, and PST score in the two groups were all improved in comparison with those before the operation ($P<0.05$). However, in the 6th month and 12th month after the operation, they showed no differences between the two groups ($P>0.05$).

Comparison of knee joint movement ability between the two groups

Single-legged hop test and the return-to-sport ratio were used to evaluate knee joint movement ability between the two groups (Table 5). As demonstrated in Table 5, there was no notable difference in term of single-legged hop test between the two groups after operation ($P=0.174$). The return-to-sport ratio in the 12th month after operation in the N1 group was significantly higher than that in the N2 group ($P<0.05$).

Complications between the two groups

The preoperative (Fig. 2 A) and postoperative (Fig. 2B) MRI images of representative cases in the N1 group, and MRI-T2 sequence diagram before (Fig. 2 C) and after (Fig. 2D) operation in the N2 group were collected to evaluate the complications between the two groups. It was found that no postoperative complications such as joint cavity infection, venous thrombosis, nerve injury, and graft failure occurred in the two groups during the follow-up period of 12 months.

Discussion

The ACL injury is regarded as one of the most common knee ligament injuries, which is associated with potential long-term complications such as chronic knee instability, meniscus tears, cartilage injury, and development of osteoarthritis (OA) [3, 4]. In this study, the clinical data, the proprioceptive threshold of passive motor perception of knee join, preoperative and postoperative IKDC scores, Lysholm score, and TAS, knee joint stability and movement ability, and complications were investigated in patients with ACL injury of the knee joint. The results showed that preserving longer stump tissue in ACL reconstruction can enhance revascularization and promote proprioception recovery. If conditions permit, the stump with a length of ≥ 1/2 should be preserved as much as possible [11].

Arthroscopic ACL reconstruction with autologous tendons has become the mainstream of surgical treatment

Table 4 Comparison of knee joint stability between the two groups

Items	Groups	Before operation				In the 6th month after the operation				In the 12th month after the operation			
		Negative	I	II	III	Negative	I	II	III	Negative	I	II	III
Lachman score	N2	0	4	6	7	11	6	0	0	12	5	0	0
	N1	0	7	6	4	13	4	0	0	13	4	0	0
χ^2		1.636				0.567				0.180			
p		0.447				0.452				0.670			
ADT score	N2	0	7	6	4	12	5	0	0	12	5	0	0
	N1	0	8	5	4	13	4	0	0	13	4	0	0
χ^2		0.158				0.151				0.151			
p		0.924				0.697				0.697			
PST score	N2	0	8	6	3	12	5	0	0	12	5	0	0
	N1	0	9	5	3	13	4	0	0	13	4	0	0
χ^2		1.292				0.151				0.151			
p		0.524				0.697				0.697			

Table 5 Comparison of knee joint movement ability between the two groups

Items	N1 group (*n* = 17)	N2 group (*n* = 17)	t	*p*
Single legged jump after operation (%)	93.00 ± 2.29	91.77 ± 2.86	1.390	0.174
Return-to-sport ratio after operation (Yes/No)	12/5	6/11	4.25	0.039

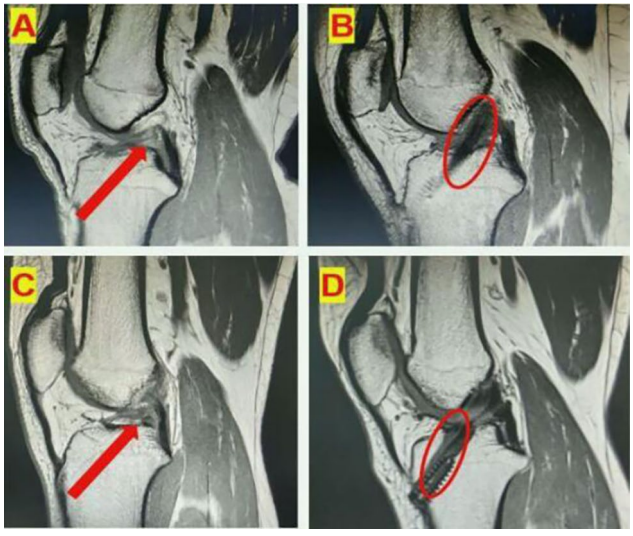

Fig. 2 The magnetic resonance imaging (MRI) images of representative cases in the two groups before and after operation. (**A**) preoperative MRI-T2 sequence diagram of a female in the N2 group who was 18 years old, with right knee joint pain caused by sprain for more than 2 months. The arrow refers to the broken end tendon; (**B**) postoperative MRI-T2 sequence diagram of a female in the N2 group, who was 18 years old, with right knee joint pain caused by sprain for more than 2 months. The circle shape refers to the good repair effect. (**C**) preoperative MRI-T2 sequence diagram of a male in the N1 group, who was 19 years old, with right knee pain caused by sprain for more than 20 days. The arrow refers to the broken end tendon; (**D**) postoperative MRI-T2 sequence diagram of a male in the N1 group, who was 19 years old, with right knee pain caused by sprain for more than 20 days. The circle shape refers to the good repair effect

for ACL injury [5]. The hamstring muscle is now the preferred ligament for ACL reconstruction [30]. Moreover, the use of the hamstring as an autologous graft has the risk of complications, such as injury of the infrapatellar branch of the saphenous nerve and decreased stability of the knee joint [31–33]. PLT has excellent biomechanical properties, including the surface position for easy and safe collection [34]. The risk of complications of PLT graft is lower than that of the hamstring [35–37]. Furthermore, for ACL reconstruction, a full-bundle autologous PLT graft can easily provide sufficient size [38, 39]. Therefore, PLT was used as an autologous graft for ACL reconstruction in this study. The clinical results were satisfactory in the 12th month after the operation without obvious complications.

This study indicated that proprioceptive threshold of measure-passive motor perception of knee join is

decreased after operation compared to that before the operation, and it is higher in N2 group than that in the N1 group. For ACL reconstruction, the significant revascularization effect is the ACL residual ligament and synovial tissue, so that it can ultimately play a key role in the blood supply. The recovery of proprioception of the knee joint mainly depends on the mechanical receptors in the ACL stump tissue [39, 40]. It is suggested that 1-2% of ACL volume is composed of mechanoreceptors, and the rupture of ACL will cause a decrease in the number of mechanoreceptors, thereby reducing their proprioception [41]. The key to the success of ACL reconstruction is not only the recovery of knee mechanical function but also the recovery of knee proprioception. Therefore, the broken ACL stump tissue should be retained as much as possible to preserve more mechanoreceptors [42].

In this study, compared with patients with a retention length < 1/2 in ACL reconstruction, patients with a retention length ≥ 1/2 have a better proprioception recovery and a higher proportion of return to exercise in the short follow-up. More complete synovial coverage provided by the stump tissue will reduce the loss of mechanoreceptors and promote angiogenesis and ligamentization of tendons [43]. Patients with longer lengths of stump tissue have better proprioception recovery. When ACL is reconstructed with remnant preservation, the more intact the tibial stump tissue is, the better the preservation of proprioceptive function is, and the prognosis of patients with a high remnant preservation rate is more satisfactory [10, 44]. When there is a large amount of residual tissue in the injured ACL, it is recommended to retain as much residual tissue as possible for reconstructing the ACL [20].

There are three limitations in this study. First, there are no surgical cases related to monocular deformity in this study. Second, the form of proprioception measurement is single, and rehabilitation training lacks standardized and unified standards. It is necessary to further increase the proprioception measurement method and strengthen the rehabilitation program. Third, there is a lack of histologically confirmed results of secondary arthroscopy, leading to a loss in analyzeing the structural relationship between the reconstructed ACL and the stump tissue.

Conclusion

In conclusion, during the 1-year follow-up period, the treatment strategy of ACL stump retention length ≥ 1/2 during ACL reconstruction with PLT is more effective than the treatment strategy of length < 1/2 for patients with ACL injury of the knee joint.

Abbreviations

ACL	Anterior Cruciate Ligament
PLT	Peroneus Longus Tendon
IKDC	International Knee Documentation Committee
TAS	Tegner Activity Score
ADT	Anterior Drawer Test
PST	Pivot Shift Test
BMI	Body Mass Index
MRI	Magnetic Resonance Imaging
CPM	Continuous Passive Motion
SD	Standard Deviation

Author contributions

CRC was responsible for the definition of intellectual content, literature research, clinical studies and manuscript preparation; ZJ was responsible for the experimental studies and data acquisition; ZML was responsible for the data analysis and manuscript editing; MHH was conducted the statistical analysis; CYB undertook the study concepts & design; LWX was responsible for the guarantor of integrity of the entire study, and manuscript review. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. and gave the final approval of the version to be published.

Funding

This study was supported by The Health Commission Self-Funded Scientific Research Projects of Guangxi, China(No. Z-C20220835) and the Partly supported by the open funds of the Guangxi Key Laboratory of Tumor Immunology and Microenvironmental Regulation (No. 2023KF007).

Data availability

All data generated or analysed during this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

This retrospective study have been performed in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of the Affiliated Hospital of Guilin Medical University, China (No. 2021TDXLYJSLL-10). All patients provided written informed consent for participation in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 8 May 2024 / Accepted: 11 April 2025
Published online: 24 April 2025

References

1. Meng JH. The effect of Xinshentong Zhuyu Decoction combined with anterior cruciate ligament reconstruction under knee arthroscopy on early postoperative rehabilitation of patients. Pract Clin J Integr Tradit Chin West Med. 2021;21(22):75–6.
2. Drigny J, Calmès A, Reboursière E, Hulet C, Gauthier A. Changes in the force-velocity relationship of knee muscles after anterior cruciate ligament reconstruction using the isokinetic 2-point model. Int J Sports Physiol Perform. 2023;18(11):1336–44. https://doi.org/10.1123/ijspp.2023-0108.
3. Filbay SR, Dowsett M, Chaker Jomaa M, Rooney J, Sabharwal R, Lucas P, Van Den Heever A, Kazaglis J, Merlino J, Moran M, Allwright M, Kuah DEK, Durie R, Roger G, Cross M, Cross T. Healing of acute anterior cruciate ligament rupture on MRI and outcomes following non-surgical management with the cross bracing protocol. Br J Sports Med. 2023;57(23):1490–7. https://doi.org/10.1136/bjsports-2023-106931.
4. Thakur U, Gulati V, Shah J, Tietze D, Chhabra A. Anterior cruciate ligament reconstruction related complications: 2D and 3D high-resolution magnetic resonance imaging evaluation. Skeletal Radiol. 2022;51(7):1347–64. https://doi.org/10.1007/s00256-021-03982-7.
5. Andonovski A, Topuzovska S, Samardziski M, Bozinovski Z, Andonovska B, Temelkovski Z. The influence of anterior cruciate ligament remnant on post-operative clinical results in patients with remnant preserving anterior cruciate

ligament reconstruction. Open Access Maced J Med Sci. 2017;5(5):624–9. https://doi.org/10.3889/oamjms.2017.096.
6. Ahn JH, Wang JH, Lee YS, Kim JG, Kang JH, Koh KH. Anterior cruciate ligament reconstruction using remnant preservation and a femoral tensioning technique: clinical and magnetic resonance imaging results. Arthroscopy. 2011;27(8):1079–89. https://doi.org/10.1016/j.arthro.2011.03.002.
7. Aly AR, Rajasekaran S, Mohamed A, Beavis C, Obaid H. Feasibility of ultrasound-guided percutaneous tenotomy of the long head of the biceps tendon-A pilot cadaveric study. J Clin Ultrasound. 2015;43(6):361–6. https://doi.org/10.1002/jcu.22189.
8. Naraoka T, Kimura Y, Tsuda E, Yamamoto Y, Ishibashi Y. Is remnant preservation truly beneficial to anterior cruciate ligament reconstruction healing? Clinical and magnetic resonance imaging evaluations of remnant-preserved reconstruction. Am J Sports Med. 2017;45(5):1049–58. https://doi.org/10.1177/0363546516682241.
9. He C, Li YL, Li XG, Wang GL, Wang JW, Cao SH, Wang HJ, Zhao FK. Analysis of the effect of anterior cruciate ligament reconstruction with remnant preservation on the recovery of knee proprioceptive function. Chin J Repar Reconstr Surg. 2014;28(4):442–7.
10. Lee BI, Kwon SW, Kim JB, Choi HS, Min KD. Comparison of clinical results according to amount of preserved remnant in arthroscopic anterior cruciate ligament reconstruction using quadrupled hamstring graft. Arthroscopy. 2008;24(5):560–8. https://doi.org/10.1016/j.arthro.2007.11.011.
11. Tonin M, Saciri V, Veselko M, Rotter A. Progressive loss of knee extension after injury. Cyclops syndrome due to a lesion of the anterior cruciate ligament. Am J Sports Med. 2001;29(5):545–9. https://doi.org/10.1177/03635465010290050401.
12. Lee JK, Jo S, Lee YL, Park H, Song JS, Sung IH, Kim TH. Anterior cruciate ligament remnant cells have different potentials for cell differentiation based on their location. Sci Rep. 2020;10(1):3097. https://doi.org/10.1038/s41598-020-60047-w.
13. Bi M, Zhao C, Zhang S, Yao B, Hong Z, Bi Q. 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. 2018;31(10):1022–30.
14. Dhammi IK, Rehan-Ul-Haq, Kumar S. Graft choices for anterior cruciate ligament reconstruction. Indian J Orthop. 2014;49(2):127–8.
15. Liu CT, Lu YC, Huang CH. Half-peroneus-longus-tendon graft augmentation for unqualified hamstring tendon graft of anterior cruciate ligament reconstruction. J Orthop Sci. 2015;20(5):854–60. https://doi.org/10.1007/s00776-015-0744-2.
16. 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. 2014;3:115. https://doi.org/10.4103/2277-9175.132696.
17. Wu SC, Zheng YC, Yan KN, Lin WX, Xu WH, Kang JX. Comparison of the efficacy of anterior cruciate ligament reconstruction with peroneus longus tendon and hamstring tendon. Chin J Rep Reconstr Surg. 2015;29(11):1358–63.
18. He C, Li YL, Li XG, Wang GL, Wang JW, Cao SH, Wang HJ, Zhao FK. Analysis of the effect of anterior cruciate ligament remnant preservation reconstruction on the recovery of proprioceptive function of knee joint. Chin J Rep Reconstr Surg. 2014;28(4):442–7.
19. Zhang QL, Zhao L, Teng XR. Clinical study on the effect of anterior cruciate ligament reconstruction with remnant preservation on proprioception recovery of knee joint. Chin J Sports Med. 2015;34(8):739–43.
20. Kim SJ, Choi CH, Chun YM, Kim SH, Lee SK, Jung WS, Jung M. Anterior cruciate ligament reconstruction using bone-patellar tendon-bone autograft with remnant preservation: comparison of outcomes according to the amount of remnant tissue. J Knee Surg. 2019;32(9):847–59. https://doi.org/10.1055/s-0038-1669902.
21. Ageberg E, Flenhagen J, Ljung J. Test-retest reliability of knee kinesthesia in healthy adults. BMC Musculoskelet Disord. 2007;8:57. https://doi.org/10.1186/1471-2474-8-57.
22. Nagai T, Heebner NR, Sell TC, Nakagawa T, Fu FH, Lephart SM. Restoration of sagittal and transverse plane proprioception following anatomic double-bundle ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2013;21(9):2048–56. https://doi.org/10.1007/s00167-012-2188-y.
23. Wang X, Han X, Shi XT, Yuan Y, Tan H. The early effect of arthroscopic single-bundle four-strand semitendinosus tendon and peroneus longus tendon anterior semitendinosus tendon bundle reconstruction of posterior cruciate ligament. Chin J Rep Reconstr Surg. 2021;35(5):556–61.
24. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med. 1982;10(3):150–4. https://doi.org/10.1177/036354658201000306.
25. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm score and Tegner activity scale for anterior cruciate ligament injuries of the knee: 25 years later. Am J Sports Med. 2009;37(5):890–7. https://doi.org/10.1177/0363546508330143.
26. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res. 1985;198:43–9.
27. Moksnes H, Engebretsen L, Risberg MA. Prevalence and incidence of new meniscus and cartilage injuries after a nonoperative treatment algorithm for ACL tears in skeletally immature children: a prospective MRI study. Am J Sports Med. 2013;41(8):1771–9. https://doi.org/10.1177/0363546513491092.
28. Fok AW, Yau WP. Associations between isolated bundle tear of anterior cruciate ligament, time from injury to surgery, and clinical tests. J Orthop Surg (Hong Kong). 2014;22(2):209–13. https://doi.org/10.1177/230949901402200219.
29. Chen M, Lin JJ, Liu WG. The effect of preserving the length of the stump on the effect of single-bundle reconstruction of anterior cruciate ligament with autologous hamstring tendon. J Pract Orthop. 2020;26(8):693–9.
30. Zhou P, Liu JC, Deng XT, Li Z. Hamstring autograft versus patellar tendon autograft for anterior cruciate ligament reconstruction, which graft has a higher contralateral anterior cruciate ligament injury rate: A meta-analysis of 5561 patients following the PRISMA guidelines. Med (Baltim). 2020;99(31):e21540. https://doi.org/10.1097/MD.0000000000021540.
31. Nelissen E, van Arkel ER, Hazelbag HM. Traumatic neuroma of the infrapatellar branch of the saphenous nerve after hamstring harvesting. J Knee Surg. 2010;23(4):233–6. https://doi.org/10.1055/s-0031-1271887.
32. Cristiani R, Sarakatsianos V, Engström B, Samuelsson K, Forssblad M, Stålman A. Increased knee laxity with hamstring tendon autograft compared to patellar tendon autograft: a cohort study of 5462 patients with primary anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2019;27(2):381–8. https://doi.org/10.1007/s00167-018-5029-9.
33. Ponzo A, Monaco E, Basiglini L, Iorio R, Caperna L, Drogo P, Conteduca F, Ferretti A. Long-term results of anterior cruciate ligament reconstruction using hamstring grafts and the outside-in technique: A comparison between 5- and 15-year follow-up. Orthop J Sports Med. 2018;6(8):2325967118792263. https://doi.org/10.1177/2325967118792263.
34. 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. 2012;40(3):662–71. https://doi.org/10.1177/0363546511428782.
35. Rhatomy S, Wicaksono FH, Soekarno NR, et al. Eversion and first ray plantarflexion muscle strength in anterior cruciate ligament reconstruction using a peroneus longus tendon graft. Orthop J Sports Med. 2019;7(9):2325967119872462.
36. Shi FD, Hess DE, Zuo JZ, 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. https://doi.org/10.1055/s-0038-1669951.
37. Palmer JE, Russell JP, Grieshober J. A Biomechanical comparison of allograft tendons for ligament reconstruction. Am J Sports Med. 2017;45(3):701–7.
38. Sahoo PK, Sahu MM. Analysis of postural control following anterior cruciate ligament reconstruction with ipsilateral peroneus longus tendon graft. Malays Orthop J. 2023;17(1):133–41. https://doi.org/10.5704/MOJ.2303.016.
39. Cao HB, Liang J, Xin JY. Treatment of anterior cruciate ligament injury with peroneus longus tendon. Zhonghua Yi Xue Za Zhi. 2012;92(35):2460–2.
40. Nayak M, Nag HL, Nag TC, Digge V, Yadav R. Ultrastructural and histological changes in tibial remnant of ruptured anterior cruciate ligament stumps: a transmission electron microscopy and immunochemistry-based observational study. Musculoskelet Surg. 2020;104(1):67–74. https://doi.org/10.1007/s12306-019-00599-x.
41. Inokuchi T, Matsumoto T, Takayama K, Nakano N, Zhang S, Araki D, Matsushita T, Kuroda R. Influence of the injury-to-surgery interval on the healing potential of human anterior cruciate ligament-derived cells. Am J Sports Med. 2017;45(6):1359–69. https://doi.org/10.1177/0363546517689871.
42. Fremerey RW, Lobenhoffer P, Zeichen J, Skutek M, Bosch U, Tscherne H. Proprioception after rehabilitation and reconstruction in knees with deficiency of the anterior cruciate ligament: a prospective, longitudinal study. J Bone Joint Surg Br. 2000;82(6):801–6. https://doi.org/10.1302/0301-620x.82b6.10306.
43. Adachi N, Ochi M, Uchio Y, Iwasa J, Ryoke K, Kuriwaka M. Mechanoreceptors in the anterior cruciate ligament contribute to the joint position sense. Acta

Orthop Scand. 2002;73(3):330–4. https://doi.org/10.1080/00016470232015535 6.
44. Chouteau J, Testa R, Viste A, Moyen B. Knee rotational laxity and proprioceptive function 2 years after partial ACL reconstruction. Knee Surg Sports Traumatol Arthrosc. 2012;20(4):762–6. https://doi.org/10.1007/s00167-012-1879-8.

Publisher's note