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Efficacy comparison between a new generation of artificial ligaments and bone-patellar tendon-bone autograft for anterior cruciate ligament revision

Summary

Objective To compare the clinical efficacy of using a new generation of artificial ligament (LARS artificial ligament) and autologous bone-patellar tendon-bone (BTPB) as grafts in anterior cruciate ligament (ACL) revision surgery.

Methods Retrospective cohort study. Retrospective analysis of the clinical data of 54 patients who underwent ACL revision surgery at the First Affiliated Hospital of Army Medical University from January 2018 to June 2020, including 44 males and 10 females; age (28.5±7.7) years (15 ~45 years old). Among them, 24 cases were revised using LARS artificial ligament (LARS group), and 30 cases were revised using autologous BPTB (BPTB group). The subjective and objective evaluation indexes of the knee joints of the two groups of patients were compared to evaluate the surgical efficacy. Among them, subjective evaluation indicators include Tegner score, Lysholm score and International Knee Documentation Committee (IKDC) score; objective evaluation indicators include Lachman test, pivot shift test, weight-bearing anterior tibial translation distance (ATT) and the patient's return to pre-injury sports. ratio.

Results The postoperative follow-up time of the patients was (32.8±5.3) months (24-42 months). At the last follow-up, the IKDC score, Tegner score and Lysholm score of the two groups of patients were all higher than those before surgery, and the differences were statistically significant (all P <0.05), while there were no statistically significant differences between the two groups (all P > 0.05); the ATT measurement in the weight-bearing position was (3.1±0.7) mm in the LARS group and (4.1±0.9) mm in the BPTB group, both of which were improved compared with those before surgery (all P <0.05). The LARS group was better than the BPTB group, and the difference was statistically significant. scientific significance (P <0.05). The LARS group was better than the BPTB group in the postoperative Lachman test and pivot shift test between the two groups, and the

differences were statistically significant (all P <0.05). The rate of patients returning to pre-injury sports 1 year after surgery was 79.2% (19/24) in the LARS group and 50.0% (15/30) in the BPTB group, and the difference was statistically significant (P =0.029).

Conclusion Both LARS artificial ligament and BPTB autograft can achieve good short-term clinical results in ACL revision surgery, but LARS artificial ligament has more advantages than BPTB autograft in terms of knee joint stability and early return to sports.

Key words:anterior cruciate ligament;renovation;graft;artificial ligaments;Bone-patellar tendon-bone

ABSTRACT

Objective To compare the clinical efficacy of a new generation of ligaments (LARS artificial ligament) and bone-patellar tendon-bone (BPTB) autograft as grafts in anterior cruciate ligament (ACL) revision.

Methods A retrospective cohort study. The clinical data of 54 patients who underwent ACL revision from January 2018 to June 2020 in the First Hospital Affiliated to Army Medical University were retrospectively analyzed. There were 44 males and 10 females with a mean age of (28.5± 7.7) years (15-45 years). Among them, 24 cases underwent ACL revision with LARS artificial ligament (LARS group), the other 30 cases underwent ACL revision with BPTB (BPTB group). The subjective and objective knee joint evaluation indexes were compared between the two groups to evaluate the clinical efficacy. The subjective evaluation indexes included Tegner score, Lysholm score and the International Knee Documentation Committee (IKDC) score. The objective evaluation indexes included the Lachman test, pivot-shift test, the anterior tibial translation (ATT) measurement at the weight-bearing position and the rate of patients returned to pre-injury sports.

Results The follow-up period was (32.8±5.3) months (24-42 months). At the last follow-up, the IKDC score, Tegner score and Lysholm score in the two groups significantly increased when compared with those before surgery (all P <0.05), and there was no significant difference in those indexes between the two groups (all P >0.05). The ATT measurement in the weight-bearing position was (3.1±0.7) mm in the LARS group and it was (4.1 ±0.9) mm in the BPTB group, which were significantly improved when compared with those before surgery (both P <0.05), and it was better in the LARS group than in the BPTB group (P <0.05). Postoperative Lachman test and pivot -shift test results in the LARS group were better than those in the BPTB group with statistically significant difference (both P <0.05). The rate of patients returned to pre-injury sports one year after surgery was 79.2%(19/24) in the LARS group and it was 50.0%(15/30) in the BPTB group, and the difference was statistically significant (P =0.029).

Conclusions Both LARS artificial ligament and BPTB autograft can achieve good short-term clinical efficacy in ACL revision, but LARS artificial ligament group has more advantages than BPTB autograft group in knee stability and early return to sports.
KEYWORDS:Anterior cruciate ligament;Revision;Graft;Artificial ligament;Bone-patellar tendon-bone
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Arthroscopic anterior cruciate ligament (ACL) reconstruction surgery is considered the standard treatment for ACL rupture [1]. Although this surgical technology is very mature, 1.7% to 10.7% of patients still suffer from postoperative complications. Recurrent knee joint instability requires revision [2,3,4,5]. As the public becomes more interested in sports and the number of primary ACL reconstruction surgeries continues to rise, ACL revision will become more popular. However, the choice of graft used in ACL revision surgery has always been controversial. Globally, autologous bone-patellar tendon-bone

(BPTB) graft is still the main choice for ACL revision surgery [6,7]. With the material innovation of the new generation of artificial ligaments, the occurrence of adverse events such as joint synovitis and early graft rupture caused by the first generation of artificial ligament products has been effectively reduced. As a representative of the new generation of artificial ligaments, the advanced ligament reinforcement system (LARS) has gradually become widely used in clinical practice due to its high strength and rapid recovery, and has achieved satisfactory mid- and long-term effects [8,9]. However, there are currently few reports on the clinical efficacy of LARS artificial ligament for ACL revision. The purpose of this study was to compare the short-term efficacy of LARS artificial ligament and BPTB autograft for ACL revision, and to explore the indications and advantages of LARS artificial ligament for ACL revision, so as to provide a reference for graft selection in ACL revision surgery.

Objects and methods

1. Research objects

Retrospective cohort study. The clinical data of patients who underwent ACL revision surgery at the Department of Joint Surgery, the First Affiliated Hospital of Army Medical University from January 2018 to June 2020 were retrospectively analyzed. Inclusion criteria: (1) Re-rupture or failure after initial ACL reconstruction; (2) Symptoms of recurrent knee instability; (3) After full communication with the physician, the patient voluntarily chooses LARS artificial ligament or autogenous ligament before ACL revision surgery BPTB was used as a graft; (4) there was no osteoarthritis manifestation on imaging; (5) the follow-up time after ACL revision was ≥24 months. Exclusion criteria: (1) Combined with multiple ligament injuries of the knee joint; (2) Combined with fractures of the affected lower limb; (3) Outerbridge cartilage grade III or above cartilage damage area exceeding 1 cm^2 ; (4) Second or more revision surgery ; (5) The first-stage revision cannot be completed due to enlargement of the initial reconstructed bone tunnel or osteolysis; (6) Significant dysfunction of the knee joint before surgery, that is, >20° of extension deficit or <80° of flexion; (7) Lower limb strength The abnormal line is >10° in the coronal plane, and the tibial plateau posterior inclination angle in the sagittal plane is >12°. This study was approved by the Ethics Committee of the First Affiliated Hospital of Army Medical University (approval number: KY202281), and all subjects gave informed consent to the study.

2. Sample size estimation

According to previous research results, the rate of returning to the pre-injury level of exercise after ACL revision with artificial ligaments is 74%, and the rate of BPTB autograft is 40.2% [10]. The type I error of hypothesis testing is set to α=0.05, type II When the error β=0.2 and the sample size ratio (k) of the experimental group and the control group is 1:1.25, according to the sample size calculation formula, the sample size of the LARS group is 21 and the sample size of the BPTB group is 26.25. Assuming that the loss to follow-up rate is 10%, the LARS group needs a sample size of at least 24 cases, and the BPTB group needs a sample size of at least 30 cases.

3. Surgical methods

According to different graft selections for ACL revision surgery, patients were divided into two groups: LARS group and BPTB group. Before surgery, the patient completed full-length anteroposterior and lateral X-rays of the lower limbs, knee CT and MRI examinations, and evaluated the location and expansion of the bone tunnel for the patient's initial ACL reconstruction to formulate a revision surgery strategy and initial graft selection. All surgeries were performed by a senior associate chief physician specializing in sports medicine. The patient was placed in the supine position under combined spinal anesthesia and epidural anesthesia. Arthroscopic exploration was performed to evaluate the continuity, tension and bone tunnel position of the primary ACL graft, damage to the medial and lateral menisci, articular cartilage, intercondylar notch osteophyte formation and degree of stenosis. According to the type and location of the meniscal tear, it should be sutured as much as possible, otherwise meniscus repair surgery will be performed; the damaged cartilage will be repaired and reshaped; intercondylar notch stenosis will be treated with intercondylar notch plasty; the broken or failed original graft stumps will be cleaned. ; Remove internal fixation that interferes with revision surgery.

LARS group: The knee of the affected lower limb was flexed 120° and placed in the figure-4 position, and a 6.0 mm eccentric femoral positioner was inserted through the arthroscopic anteromedial approach to assist isometric point positioning. Place the positioner on the apex of the posterior cartilage edge, rotate the opening plane of the positioner to the level of the tibial plateau, and then drill the guide pin to the contralateral cortical bone and penetrate the lateral femoral skin. A 2 cm surgical incision was made at the exit point. Under the protection of the soft tissue sleeve, a femoral tunnel with a diameter of 7.5 mm was drilled from the outside to the inside. The bone debris in the tunnel was carefully cleaned and observed to see if it overlapped with the original bone tunnel. The knee joint is positioned at 90° of knee flexion, a 1.5 cm surgical

incision is made at the original surgical scar on the inner side of the tibial tubercle, and the tibial position is positioned at 55° between the LARS ligament tibial positioner and the tibial plateau. The tibial site is selected at the intersection of the horizontal extension line of the free edge of the lateral meniscus and the midline of the tibial intercondylar ridge, and a 7.5 mm diameter drill is made to clear the bone debris in the tunnel. The LARS artificial ligament (AC 120 2B) is introduced into the bone tunnel. According to the patient's bone condition, the outer openings of the femoral and tibial tunnels are extruded and fixed at the bone cortex with an adapted titanium screw.

BPTB group: Make a longitudinal incision of about 2 cm on the lower pole of the ipsilateral patella and a 4 cm incision on the original tibial scar. Obtain 1/3 of the patellar tendon with a width of about 10 mm and connect the bone fragments at both ends of the patella and tibial tubercle. The two ends are trimmed. The end bone block is placed and the traction wire (femur)/steel wire (tibia) is placed for later graft preparation. The preparation position and positioning of the femoral tunnel were the same as in the LARS group. A bone tunnel with the same diameter as the bone block was drilled from the inside out, with a length of 3 cm (the length of the bone block was taken to be 2.5 cm). The tibial positioner angle was selected according to the "N+7 principle" [11], that is, the patellar tendon length of the graft was positioned at +7° to minimize the problem of graft-tunnel mismatch. The rest of the preparation methods were the same as in the LARS group. After the autologous BPTB graft was introduced from the tibial tunnel, both ends were fixed with adapted polyetheretherketone interface screws.

4. Postoperative recovery

The weight-bearing time of the affected limb after surgery depends on the integrity of the meniscus fibrosus annulus. If the meniscus fibrosus annulus is completely broken (radial tear, root tear), there will be no weight-bearing for 6 weeks after suturing. If the meniscus fibrosus annulus is intact or has no tear, of patients followed the following rehabilitation principles (Table 1).

Read more

time	LARS group (*n* =24)	BPTB group (*n* =30)
0~2 weeks	ROM 0~90°, the affected limb is not	ROM 0~90°, the affected limb is not weight-bearing

time	LARS group (*n* =24)	BPTB group (*n* =30)
	weight-bearing	
3~4 weeks	ROM 0~120°, partial load bearing under the protection of the brace	ROM 0~100°, partial load bearing under the protection of the brace
5~6 weeks	Restore the full angle of the knee joint and allow full weight-bearing under the protection of the brace	ROM 0~120°, partial load bearing under the protection of the brace
7~8 weeks		Restore the full angle of the knee joint and allow full weight-bearing under th
9~12 weeks	Jogging and other non-axis shifting sports	
13~16 weeks		Jogging and other non-axis shifting sports
17~24 weeks	non-contact pivot movement	

time	LARS group (*n* =24)	BPTB group (*n* =30)
25~36 weeks	Contact Pivot Movement	non-contact pivot movement
After 36 weeks		Contact Pivot Movement

Table 1Rehabilitation methods after anterior cruciate ligament revision surgery in two groups

Note: LARS stands for Advanced Ligament Reinforcement Device; BPTB stands for Bone-Patellar Tendon-Bone; ROM stands for joint range of motion.

5. Efficacy evaluation indicators

Postoperative complications and the patient's time to return to preinjury sports were recorded. All patients were evaluated using Tegner activity level score (0 to 10 points), Lysholm knee function score (0 to 100 points), and International Knee Documentation Committee (IKDC) score (0 to 100) before surgery and at the final follow-up. points) to evaluate the improvement of subjective function of the knee joint. The Lachman test, pivot shift test and anterior tibial translation (ATT) in weight-bearing position were used to evaluate knee joint stability. Lachman test: Grade I laxity is an anterior translation of the tibia of 0 to 5 mm; Grade II laxity is an anterior translation of the tibia of 6 to 10 mm; Grade III laxity is an anterior translation of the tibia >10 mm [12]. The axis shift test is divided into 4 levels: 0 degree is normal; Ⅰ degree is sliding during reduction; Ⅱ degree is bouncing during reduction; Ⅲ degree is anterior tibial subluxation or joint interlocking during reduction [13]. ATT measures the anterior translation distance of the tibia relative to the femoral condyle on the full-length lateral X-ray of the lower limb (standing position), and draws a line connecting the midpoints of the anterior and posterior tibial cortex below the tibial tubercle and on the ankle joint to determine the tibial shaft axis. Draw parallel lines to the axis of the tibial shaft through the most posterior edge of the femoral condyle (if the inner and outer femoral condyles do not completely overlap, take the midpoint of the most extreme edge of the inner and outer femoral condyle) and the most posterior edge of the tibial plateau, the distance between the two parallel lines is the anterior tibial moving distance. If the parallel line of the posterior edge of the tibial plateau is in front of the parallel line of the posterior edge of the femoral condyle, it is a

positive number, and vice versa [14]. All data were measured three times by the same physician and then averaged.

6. Statistical methods

This study uses SPSS 26.0 statistical software for data analysis. General data uses statistical description, and measurement data consistent with normal distribution uses$\bar{x}\pm s_{\bar{x}}\pm s$*said that the paired samples t* test was used to compare before and after surgery , and the independent samples *t* test was used between the two groups. Count data are expressed as cases (%), and comparisons between groups were performed using the Mann-Whitney *U* rank sum test. For two-sided testing, take α=0.05.

result

1. Basic situation

A total of 54 patients were included in this study, including 44 males and 10 females; aged (28.5±7.7) years old (15-45 years old). There were 24 patients in the LARS group, 20 males and 4 females; age (28.3±7.5) years old (15-44 years old). The initial ACL reconstruction procedures were all single-bundle reconstructions, including 23 cases of autograft reconstruction (21 cases of hamstring tendon, 2 cases of BPTB) and 1 case of allograft reconstruction (BPTB). Reasons for failure of ACL reconstruction: traumatic re-rupture in 15 cases, non-traumatic re-rupture in 5 cases, graft relaxation in 3 cases, and graft absorption in 1 case. The interval between the initial ACL reconstruction and the current revision was (28.5±10.4) months (13-49 months). There were 30 patients in the BTPB group, 24 males and 6 females; age (28.7±7.9) years old (17-45 years old). The initial ACL reconstruction procedures were all single-bundle reconstructions, including 27 cases of autograft reconstruction (hamstring tendon) and 3 cases of LARS artificial ligament. Reasons for failure of ACL reconstruction: traumatic re-rupture in 17 cases, non-traumatic re-rupture in 4 cases, graft relaxation in 8 cases, and graft absorption in 1 case. The interval between the initial ACL reconstruction and the current revision was (29.9±10.0) months (13-47 months). There was no statistically significant difference in the general information between the two groups (both $P>0.05$), and they were comparable (Table 2).

Read more

project	LARS group (*n* =24)	BPTB group (*n* =30)	*t* /Z value	*P* value
age,$\bar{x} \pm s_{\bar{x}} \pm s$)	28.3±7.5	28.7±7.9	0.19	0.848
Gender (e.g. male/female)	20/4	24/6	-0.31	0.760
BMI (kg/m^2 ,$\bar{x} \pm s_{\bar{x}} \pm s$)	24.8±2.7	24.5±2.6	-0.42	0.677
Reason for revision (eg, traumatic/non-traumatic)	15/9	17/13	-0.43	0.670
Interval between two surgeries (months,$\bar{x} \pm s_{\bar{x}} \pm s$)	28.5±10.4	29.9±10.0	0.49	0.627
Follow-up time (months,$\bar{x} \pm s_{\bar{x}} \pm s$)	33.4±5.3	32.4±5.3	-0.67	0.505

Table 2General information of patients with anterior cruciate ligament revision in two groups

Note: LARS stands for Advanced Ligament Reinforcement Device; BPTB stands for Bone-Patellar Tendon-Bone; BMI stands for Body Mass Index

2. Surgical complications

All patients were followed up for (32.7±5.3) months (24-42 months). The patient did not suffer from postoperative complications such as poor incision healing/infection, venous thrombosis of the lower limbs, and vascular and nerve damage. One patient in the LARS group had pain at the lateral femoral skin incision 17 months after surgery, and the pain was relieved after the femoral and tibial internal fixation screws were removed. One patient in the BPTB group underwent manual release under inhaled general anesthesia due to flexion dysfunction 3 months after surgery, and the postoperative functional recovery was good.

3. Comparison of efficacy evaluation indicators for ACL revision surgery using two types of grafts

At the last follow-up, the subjective evaluation indexes IKDC score, Tegner score and Lysholm score of the two groups of patients were higher than those before surgery, and the differences were statistically significant (all P <0.05). There were no statistically significant differences between the two groups (all P >0.05); ATT measurement in the patient's weight-bearing position was (3.1±0.7) mm in the LARS group and (4.1±0.9) mm in the BPTB group, both improved compared with preoperative (all P <0.05). The LARS group was better than the BPTB group, and the differences were as follows Statistical significance (P <0.05) (Table 3). At the final follow-up, the LARS group was better than the BPTB group in the Lachman test and pivot shift test between the two groups, and the differences were statistically significant (all P < 0.05). The rate of patients returning to pre-injury sports was 79.2% (19/24) in the LARS group and 50.0% (15/30) in the BPTB group 1 year after surgery, and the difference was statistically significant (Z =-2.18, P =0.029) ; However, at 2 years after surgery, the rate was 87.5% (21/24) in the LARS group and 86.7% (26/30) in the BPTB group. The difference was not statistically significant (Z =-0.09, P =0.928), see Table 4 .

Read more

project	LARS group (n =24)	BPTB group (n =30)	t value	P value
IKDC score (points)				
Preoperative	48.0±6.0	48.9±6.0	0.55	0.586
Last follow-up	81.0±5.4	82.0±5.5	0.66	0.510
t value	-30.10	-25.63		
P value	<0.001	<0.001		
Lysholm score (points)				
Preoperative	45.9±6.0	46.8±6.0	0.56	0.576
Last follow-up	84.0±5.4	85.0±5.3	0.68	0.498

project	LARS group (*n* =24)	BPTB group (*n* =30)	*t* value	*P* value
t value	-34.89	-30.35		
P value	<0.001	<0.001		
Tegner rating (points)				
Preoperative	3.5±0.8	3.3±0.8	-0.11	0.910
Last follow-up	6.7±1.1	6.5±0.8	-0.51	0.610
t value	-21.80	-55.65		
P value	<0.001	<0.001		
ATT(mm)				
Preoperative	7.7±1.5	7.6±1.6	-0.27	0.786
Last follow-up	3.1±0.7	4.1±0.9	4.76	<0.001
t value	19.77	16.07		
P value	<0.001	<0.001		

table 3Comparison of observation indicators before and after surgery between two groups of patients with anterior cruciate ligament revision ($\bar{x} \pm s_{\bar{x}} \pm s$)

Note: LARS is advanced ligament augmentation device; BPTB is bone-patellar tendon-bone; IKDC score is International Knee Documentation Committee score; Lysholm score is knee joint function score; Tegner score is activity level score; ATT is anterior tibial translation distance.

project	LARS group (*n* =24)	BPTB group (*n* =30)	*Z* value	*P* value
Lachman test			-2.08	0.038

project	LARS group (*n* =24)	BPTB group (*n* =30)	*Z* value	*P* value
I degree	20 (83.3)	17 (56.7)		
II degree	4 (16.7)	13 (43.3)		
Axis shift test			-2.18	0.030
0 degree	22 (91.7)	20 (66.7)		
I degree	2 (8.3)	10 (33.3)		
Return to pre-injury sports				
1 year after surgery	19 (79.2)	15(50.0)	-2.18	0.029
2 years after surgery	21 (87.5)	26 (86.7)	-0.09	0.928

Table 4Comparison of the final follow-up physical examination and return-to-sport rate between the two groups of patients with anterior cruciate ligament revision [Examples (%)]

Note: LARS stands for Advanced Ligament Reinforcement Device; BPTB stands for Bone-Patellar Tendon-Bone

discuss

The goal of ACL reconstruction or revision surgery is to restore knee stability so the patient can return to sports. The presence or absence of bone tunnel enlargement or osteolysis is one of the important factors that determine whether ACL revision requires staged surgery [15]. Usually, when the bone tunnel expansion that interferes with the revision surgery after the initial reconstruction is less than 14 mm, one-stage ACL revision can be performed [16]. Autografts are still the first choice for ACL revision grafts,

especially bone grafts such as BPTB and quadriceps tendon-bone, which can fill bone defects well [17]. Limited by the influence of primary reconstruction grafts, allografts are more commonly used in revision surgeries, but their failure rate is significantly higher than that of autografts (2.78 times) [18], and there are also risks of infection, disease transmission, etc. risk. The LARS artificial ligament has the advantages of high mechanical strength, no donor site complications and rejection reactions, high immediate postoperative tensile strength and is not affected by the biological healing of the graft. It also provides a reliable graft choice for ACL revision surgery. However, the selection of ACL revision graft should also consider a variety of clinical factors, including the reason for the failure of the primary ACL reconstruction, the type of graft used initially, the available autograft tissue, the fixation method and location of the primary reconstruction, the patient's bone condition, The condition of the ipsilateral or contralateral patellofemoral joint, the size of the bone defect, and the patient’ s personal preference, etc. [19] The failure of primary ACL reconstruction is the result of the interaction of multiple factors. Each factor affects each other. The reasons include patient-related factors, surgery-related factors and biological-related factors. Among them, surgical technical errors accounted for 64.5% [20], especially the femoral tunnel positioning. Errors are the main reason for ACL reconstruction failure [21]. Therefore, accurate assessment of the position and enlargement of the femoral tunnel in primary ACL reconstruction is crucial to the selection of grafts and even surgical planning for revision surgery. Magnussen et al [22] proposed a classification of the femoral tunnel location for primary ACL reconstruction based on three-dimensional CT reconstruction to guide revision surgery planning. Based on this classification, the author believes that the selection of ACL revision grafts can follow the following principles. If the primary femur is accurately positioned (Magnussen type I) and the bone tunnel is expanded <14 mm, a thick graft can be selected; if the primary femoral tunnel overlaps with the revision tunnel (Magnussen type II)) ≤1/3 or ≥2/3 can be selected with bone graft [19]; if the femoral tunnel positioning is completely wrong (Magnussen type III) or if bone graft is used for primary reconstruction, any graft can be used to prepare a new bone tunnel for revision Operation.

BPTB autograft is considered the “gold standard” for ACL revision grafts [23] and is suitable for most primary ACL revision surgeries. Shelbourne et al [24] reported 259 patients who underwent ACL revision with BPTB autograft. The average postoperative follow-up was 7.2 years. The re-injury rate of the affected ACL was only 3.4%, and the rate of patients returning to their pre-injury sports level was 68%. Although BPTB autograft

has achieved good clinical results after ACL revision surgery, its donor site complications and graft-tunnel mismatch are also concerning. Multiple studies have shown that the incidence of anterior knee pain after BPTB autograft ACL reconstruction is 17% to 48% [24, 25, 26], and the incidence of intraoperative or postoperative patellar fracture is 0.2% to 1.3% [27]. When the relative length of the BPTB autograft exceeds the total length of the femoral tunnel, intra-articular ACL distance, and tibial tunnel, causing the tibial fragment to protrude beyond the external tibial orifice, graft-tunnel mismatch occurs, with an incidence of up to 26% [28], this phenomenon may cause complications such as reduced graft mechanical strength, relaxation, bone tunnel expansion, and impact [29]. In view of the above defects of BPTB autograft, LARS artificial ligament can be a good alternative for graft selection in some ACL revision cases. LARS artificial ligament has greatly improved compared with previous products in terms of graft failure rate and synovial inflammatory reaction. Batty et al. [30] conducted a systematic review of various types of artificial ligaments. Among them, LARS artificial ligament is used for ACL reconstruction. The failure rate was only 2.6%, and the synovial inflammatory reaction rate was 0.2%. In addition, the tensile strength of the LARS artificial ligament can reach 4 500 N (the products used in this study are all AC 120 2B), which has ultra-high mechanical strength and is a 1/3 BPTB graft with a diameter of 10 mm (2 977 N [31]) 1.5 times. LARS artificial ligament provides immediate stability to the knee joint after reconstruction, and does not require ligamentation process after implantation in the human body, and there is no risk of early graft strength attenuation, so that patients can achieve rapid recovery and early return to sports [32]. This study found that patients in the LARS artificial ligament group had better knee joint stability than the BPTB autograft group in terms of postoperative imaging evaluation and physical examination, and the rate of return to pre-injury sports in the LARS group 1 year after surgery was 79.2%. , the rate in the BPTB autograft group was 50.0%. However, 2 years after surgery, the rates of patients in the two groups returning to pre-injury sports were 87.5% and 86.7% respectively. There was no statistically significant difference in the results between the two groups, which shows that The LARS artificial ligament group can return to pre-injury sports earlier, which is consistent with previous studies showing that artificial ligaments can return to sports earlier than autografts [9].

Since the LARS artificial ligament is woven from polyethylene terephthalate fibers, its lack of extensibility requires the ACL reconstruction to follow the principle of "isometric" or "quasi-isometric" reconstruction, otherwise the graft will be too long in the knee. During joint flexion and extension, excessive stress will be endured, leading to knee joint

dysfunction, and even ligament relaxation or rupture in the long term [33, 34]. The consensus of "Selection of Surgical Indications for New Generation of Artificial Ligaments for Anterior Cruciate Ligament Reconstruction" states that the new generation of artificial ligaments can be used for ACL revision surgery, but patients must be carefully selected (high consensus) [35]. Therefore, in ACL revision surgery, whether the primary reconstruction bone tunnel can be filled or avoided to achieve isometric positioning of the graft is a prerequisite for using the LARS artificial ligament. Secondly, it should also be considered whether the bone surrounding the patient's bone tunnel can achieve strong fixation, especially the bone quality at the outer mouth of the tunnel. The author believes that the initial femoral positioning is Magnussen type I: the initial isometric reconstruction and the bone tunnel expansion is <9 mm can be revised with LARS artificial ligament (product type is AC 160 2B and below), and the initial anatomical center point reconstruction can be performed with LARS artificial ligament, etc. Long reconstruction and revision; the initial femoral tunnel is positioned as Magnussen type III or a bone graft is used, and a new bone tunnel can be prepared with LARS artificial ligament for revision surgery; the initial femoral tunnel is positioned as Magnussen type II, and it is not recommended to use LRAS due to the partial overlap of the old and new tunnels. Artificial ligaments serve as revision grafts.

In summary, both LARS artificial ligament and BPTB autograft can achieve good short-term clinical results in ACL revision surgery, and both can be used as reliable choices for ACL revision grafts. The LARS artificial ligament is suitable for ACL revision surgery that can fill or avoid the initial bone tunnel reconstruction and achieve isometric reconstruction. It has more advantages than the BPTB autograft in terms of knee joint stability and early return to sports.