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Original Article

The comparison of clinical efficacy of arthroscopic anterior cruciate ligament reconstruction via autologous bone-patellar tendon-bone, autologous hamstring tendon and allogeneic bone-patellar tendon-bone

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Abstract: Objective: To compare the clinical efficacy of anterior cruciate ligament (ACL) reconstruction via autologous bone-patellar tendon-bone (auBPB), autologous hamstring tendon (auHT) and allogeneic bone-patellar tendon-bone (alBPB) under arthroscope. Methods: One hundred and thirty four cases of patients who accepted ACL reconstruction in our hospital from December 2013 to January 2016 were randomly assigned to three groups: auBPB group (n=40), auHT group (n=59), alBPB group (n=35). The operative time, hospital days, postoperative fever time, Lysholm, Tegner and IKDC knee functional scores at the eighteenth month of follow-up, Lachman test results, pivot-shift test results and the incidence of adverse events of each group were observed and compared. Results: There was no significant difference in general conditions, injury time, stoller grade classification, Lysholm, Tegner and IKDC scores at the eighteenth month of follow-up, the results of Lachman test and pivot-shift test, postoperative average fever time, hospital days, the incidence of postoperative deep venous thrombosis and infection among three groups (all P>0.05). The operative time of alBPB group was significantly shorter than those of the other two groups (P<0.05). The anterior knee pain of auBPB group was significantly more than those of the other two groups (P=0.003 vs. auHT, P=0.029 vs. alBPB). Conclusion: All the reconstruction of ACL via auBPB, auHT and alBPB could achieve positive postoperative knee joint stability, but the incidence of postoperative anterior knee pain after reconstruction of ACL via auBPB was higher.

Keywords: Anterior cruciate ligament, bone-patellar tendon-bone, hamstring tendon, autologous, allogeneic

Introduction

Anterior cruciate ligament (ACL) is a critical structure to maintain the stability of knee joints, it originates from the inside of femoral condyle, extends in the direction of anteromedial and inferior side and terminates in front of intercondylar eminence of tibia and divides into anteromedial bundle and posterolateral bundle [1]. The ACL injury is mainly caused by high tension and stress of the knee joint and becomes common in soccer players. It will bring patients with knee joint instability and its common symptoms are knee swelling, soft legs, dislocation, running disability and so on. However, the injury caused by traffic accidents also increased significantly recently.

Reconstruction of injured ACL has been a general consensus for a long time. Arthroscopic ACL reconstruction can reduce the injury of knee cartilage, meniscus, etc., retain the maximum knee joint function and promote the recovery of knee joint stability. With the popularity of arthroscopy in 1980s, arthroscopic reconstruction of ACL via autologous bone-patellar tendon-bone (auBPB) has long been considered as the gold standard for treatment. However, there have been many complications, such as donor-area injury which affected the early recovery, knee extension weakness, anterior knee pain, patellar fracture and so on [2]. Recently, the ligament transplantation of auBPB and allogeneic bone-patellar tendon-bone (alBPB) has been concerned. Generally speak-

ing, auBPB and alBPB are beneficial to the recovery of knee joint function, having safe and reliable effects. The operation of autologous hamstring tendon (auHT) is simple and it has no postoperative rejection reaction and less self-injury; accurate positioning for the reconstruction of the femoral tunnel via the joint line of knee joint; tendon graft fixation greatly improves the muscle strength and the proprioception and stability of joints; as well as the promotion of the joint application of tendon bone healing methods, for example, the plasma with bone morphogenetic protein factor as well as platelets was injected into tendon bone tunnel and periosteum wrapping tendon graft; moreover, the input of bone marrow stromal stem cells and other methods contribute to the improvement of ACL reconstruction greatly. However, the advantages and disadvantages of these three methods (auBPB, alBPB and auHT) are still controversial. In 2009, Zheng et al. compared the three kinds of grafts and found that there was no significant difference in the curative effects among them, but there was no postoperative follow-up for the patients, comparative study on the postoperative long-term knee function or the postoperative evaluation of stability of the patients in the three groups [3].

This research compared and evaluated the benefits and harms of single beam reconstruction of ACL via auBPB, auHT and alBPB under arthroscopy, which based on the effects of three methods on Lysholm, Tegner and IKDC postoperative knee function scores, anterior and posterior knee joints and its rotational stability after discharge and follow-up period of patients, so as to provide clinical guidance for patients and operators.

Since December 2013, the three methods (auBPB, auHT and alBPB) were respectively applied in the single-bundle reconstruction of ACL under arthroscope, and then the knee function scores of the three groups were recorded while the differences among three groups were compared. The purpose of this study was to define the treatment of allograft, analyze the significance of the femoral tunnel and the retained stump in ACL reconstruction and compare the differences of clinical efficacy of the three kinds of transplants in the reconstruction of ACL.

Materials and methods

General materials

One hundred and thirty four patients undergoing ACL reconstruction in our hospital from December 2013 to January 2016 were included in this research. The patients were randomly assigned to three groups: auBPB group (40 cases), auHT group (59 cases) and alBPB group (35 cases). This study was approved by the ethics committee and all the patients and families signed the informed consent voluntarily.

Inclusion criteria: Patients who were diagnosed with simple ACL injuries or with meniscus injuries grade I according to Stoller method in nuclear magnetic resonance; patients enrolled without restriction of gender and age.

Exclusion criteria: Patients who were in the growth development period and were with open epiphysis in metaphysis of femur and tibial-shaft; patients with obvious osteoporosis; patients who had received ACL revision surgery; patients with the ACL injuries, moderate and severe meniscus injuries, multiple ligament injuries or other serious systemic diseases.

Operation methods

General procedures

All the operations were performed by the same orthopedist and all the patients received general anesthesia. During the operation, patients were maintained at supine position. When the lower limb ischemia occurred in the affected side, balloon tourniquet was used to stanch the bleeding in the roots of thigh. After performing arthroscopy through anterolateral entrance, the orthopedist made a definitive diagnosis, removed proliferative periosteum, exposed the ACL starting and ending points and then preserved the ACL stump of 7 mm [4-6].

AuBPB procedures

During the operation, the auBPB was cut from the superior-inferior-transversal incision. First, the orthopedist crosscut each layer on patellar tendon insertion of patella to expose the patella insertion and cut the bone attached to the middle part (1/3) of patellar tendon using tho-

Table 1. Comparison of general condition of patients in three groups

Group	Cases		Age (years old)	Time of injury (d)	Stoller classification	
	Male	Female			Degree 0	Degree I
AuBPB	29	11	35.20±14.92	13.26±15.83	17	23
AuHT	40	19	37.46±17.11	15.01±19.34	23	36
AlBPB	27	8	33.15±14.27	13.19±16.12	15	20
P	0.6172		0.4321	0.8433	0.9111	

Table 2. Comparison of Lysholm, Tegner and IKDC scores of patients within three groups and among three groups

Group	Lysholm scores	Tegner scores	IKDC scores	Lachman test		Pivot-shift test	
				N	P	N	P
AuBPB	89.96±10.42	8.58±1.76	89.31±8.22	31	9	30	10
AuHT	91.07±11.23	8.90±1.62	90.24±9.11	46	13	43	16
AlBPB	91.35±9.89	8.71±1.44	88.63±8.57	28	7	28	7
P	0.8274	0.6174	0.6743	0.672		0.327	

Note: N: negative; P: positive.

racic pendulum saw, which was approximately 10-11 mm in diameter and 20 mm in length. Afterwards, the orthopedist made the transverse incision on patellar tendon insertion of tibia in order to take the bone on the tibial side. The complex was trimmed and then a hole was drilled on the bone of the lateral patella side and a wire was threaded as a reserve for operation.

AuHT procedures

Hamstring tendon included semitendinosus and gracilis muscle tendon. Generally, the knee side of affected joint was taken to perform a longitudinal incision about 3 cm below in tibial tubercle. Goose foot gracilis muscle which was attached to tibia with semitendinosus was exposed and both of them were cut by tendon device. After the trimming, tendons were folded into 4 strands and Johnson & Johnson No. 2 non absorbable thread was braided to 10 cm as a reserve.

AlBPB procedures

First, all the donors were carefully selected and those with infectious diseases such as hepatitis, tuberculosis, syphilis and acquired immune deficiency syndrome and so on were excluded. AlBPB had the same operative method as auBPB procedures. Then the patellar tendons were flushed, put in a vacuum bag and reserved in deep low temperature at -70 to -80°C. When it comes to use, both of them were folded into 4 strands and Johnson & Johnson No. 2 non absorbable thread was used to braid tendons to 10 cm as a reserve.

ACL reconstruction

Anteromedial portal (located at the junction of about 1 cm above inside joint line of knee and about 0.5 cm from inside margin of patellar tendon) was inserted a catheter needle with the diameter of 2.5 mm when the knee joint flexed to about 120°. The insertion depth was from anteromedial portal to the stump of ACL femoral insertion. Then the internal orifice of femoral tunnel was located and the tendon tunnel in femoral outside ankle cortex was created by hollow drill needle with the diameter of 4.5 mm. Next, the knee joint was flexed to about 90° and tibial tunnel locator was used to locate the inlet of the stump of ACL tibia. The angle of tibial tunnel locator was adjusted to 45° and the guide pin was drilled along at an angle of 15° deviating in Sagittal Plane. And then tibial tunnel was created by hollow drill needle whose diameter was corresponded with tendon. After that, a prepared tendon was inserted from the external aperture of tibial tunnel into femoral tunnel and tensed at the end of tibia. After the fixing of the tendon at femoral end, the assistants performed posterior drawer test to the knee joints of patients. And the fixing of the tendon was made by absorbable interference screw at the external aperture of tibial tunnel. When the reconstruction was finished, the knee joint was flexed and extended to make sure the tension and walking condition of grafts under the arthroscopy, thereby judging whether it would hit intercondylar fossa or not.

Postoperative rehabilitation

After operation, conventionally use first generation cephalosporin antibiotics for 1 day to pre-

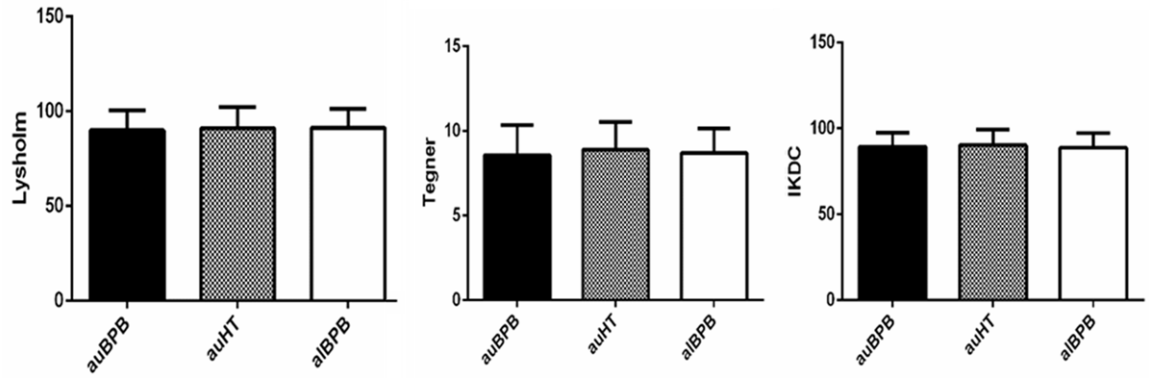

Figure 1. Comparison of Lysholm, Tegner and IKDC scores among three groups.

vent infection for patients in three groups, who also need to wear adjustable chuck knee braces for protection. From the second day after operation, patients did long contraction practice, the ankle pump exercises on quadriceps and other muscle and walked with crutch under the protection of extended braces. After three weeks, patients did knee flexion exercises and the angle of knee flexion was increased gradually. The knee was flexed to 90° in the fifth week, 120° in the sixth week and then normal position in the eighth week. After six months, patients could live without brace after three months and go jogging. One year after operation, patients were allowed to do high intensity physical exercises and athletes could resume regular exercises.

Collection of data and follow-up indexes

Collect all the general information of all the patients, which consisted of age, gender, injury time, operative time, hospital days and so on. All patients were examined by magnetic resonance on affected side of knee joint before hospital discharge and taken outpatient follow-up in the first month after operation, which was then held quarter-yearly. The follow-up indexes consisted of Lysholm, Tegner and IKDC knee functional scores and results of Lachman test and pivot-shift test.

Observation indexes

Major observation indexes: Lysholm, Tegner and IKDC knee functional scores [7, 8]. Secondary observation indexes: The results of Lysholm trial and pivot-shift test to evaluate the stability of knee joint for anteroposterior stretch and rotation, operative time, postoperative fever time and the number of patients who suffered from anterior knee pain, deep vein thrombosis and infection respectively [8, 9].

Statistical analysis

All the data were analyzed using the SPSS18.0. The count data were expressed by percentage, and measurement data were expressed by mean ± standard deviation. For the operative time, hospital days, postoperative fever time, the Lysholm, Tegner and IKDC knee functional scores at the eighteenth month of follow-up, the results of the Lachman trial and pivot-shift test, the incidence of adverse events and other observation indexes in each group, the one-way ANOVA was used for the comparison among groups and the post hoc Newman-Keul test was used for comparison in pairs. The χ^2 test was used for the comparison of the degrees of meniscus injury and the results of Lachman trial and pivot-shift test. $P<0.05$ was considered statistically significant.

Results

General information of patients in three groups

There was no statistically significant difference in age, time of injury and stroller classification of patients in three groups ($P>0.05$, **Table 1**).

Evaluation of the function and stability of knee joint of patients in three groups

There was no statistically significant difference in Lysholm, Tegner and IKDC scores of three

Table 3. Comparison of adverse events of patients in three groups

Group	Fever time (d)	Deep venous thrombosis (cases)	Anterior knee pain (cases)	Infection (cases)
AuBPB	3.13±1.12	0	7	0
AuHT	3.11±1.04	2	0*	0
AlBPB	3.51±1.46	1	1*	1
P	0.8775	0.836	0.034	0.925

Note: *P<0.05, *vs.* auBPB.

Table 4. Comparison of operative time and hospital days of patients in three groups

Group	Hospital day (d)	Operative time (min)
AuBPB	10.82±2.91	62.74±12.17*
AuHT	10.15±2.69	60.97±10.36*
AlBPB	11.02±3.32	53.41±9.03
P	0.3154	0.0004

Note: *P<0.05, *vs.* alBPB.

groups at the eighteenth month of follow-up (P>0.05, **Table 2** and **Figure 1**).

Postoperative fever time and adverse events

There was no statistically significant difference in mean postoperative fever time and incidence of adverse events (deep venous thrombosis and infection) among three groups (P>0.05). The numbers of patients who suffered from the anterior knee pain in three groups were 7 (17.50%), 0 (0%) and 1 (2.86%) respectively. Cases of anterior knee pain in auBPB group were significantly more than those in the other two groups and the differences had statistical significance (P<0.05, **Table 3**).

Operative time and hospital days

There was no statistical difference in hospital days of patients among three groups (P>0.05). The operative time in alBPB group was significantly shorter than those in auBPB group and auHT group (P<0.05) (**Table 4**; **Figure 2**).

Discussion

ACL is one of the important ligaments maintaining the stability of knee joint and the reconstruction after its fracture has long been the focus of experts. This study compared the clinical differences of three grafts-auBPB, auHT and alBPB. We found that there was no significant difference in the postoperative Lysholm, Tegner and IKDC knee function scores of these three grafts. And there was no statistical difference in the evaluation to the anterior and posterior, and rotational stability of knee joint in Lachman test and pivot-shift test. There was no difference in postoperative fever time, hospital days, incidence of infection and deep venous thrombosis in three groups. However, the operative time of autologous grafts was significantly longer than that of allogeneic grafts. After the graft of autogenous patellar tendon, the incidence of anterior knee pain in auBPB group was higher than those in the other two groups.

The grafts of the reconstruction of ACL included three types: autologous tendon, allogeneic tendon and artificially synthesized tendon. Autologous tendon has been the most common treatment method, because it had no immune rejection and low incidence of infection and even it would not deteriorate condition like other type of grafts except from influencing the stability of knee joint if the graft failed. Treatment via auBPB could well maintain the stability and function of knee joint after ACL reconstruction and accelerate healing between bones, which was once thought to be the gold standard for ACL reconstruction, thereby being widely used [10, 11].

However, some studies showed that it would increase the incidence of postoperative anterior knee pain in recent years [12, 13]. This study also indicated that the incidence of anterior knee pain in auBPB group was 17.50%, which was significantly higher than those in the other two groups. Besides, some researches were indicative of the limitation of extension function after the graft of bone-patellar tendon-bone. Therefore, many clinical workers started to use new types of grafts.

The hamstring tendon, the hot spot of researches in recent years, mainly referred to the semitendinosus and the gracilis muscle tendon. The initial tensile strength of the 4-strand hamstring tendons reached 4589N, and the maximum fracture strength of normal ACL was 1730N [14]. In this research, we used 4-strand hamstring tendons to reconstruct ACL, and

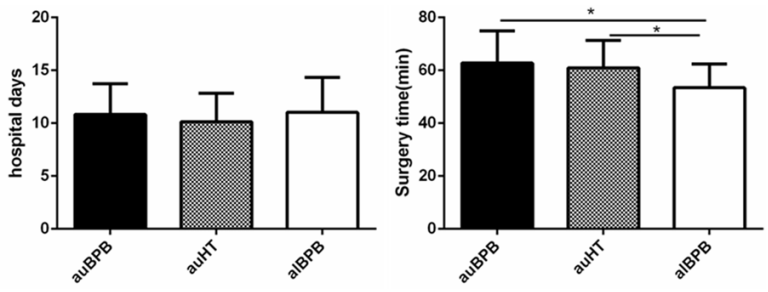

Figure 2. Comparison of hospital days and operative time among three groups. *P<0.05. *vs.* alBPB.

there was no significant difference in function scores and stability results of postoperative knee joint compared with auBPB. And due to the small impact of hamstring tendon on the local knee area, the incidence of postoperative anterior knee pain was reduced, which was consistent with the results of Laoruengthana and other studies [15-17]. These advantages made the auHT become the most commonly used graft for the current ACL reconstruction.

Allogeneic grafts of ACL reconstruction included bone-patellar tendon-bone, achilles tendon, fascia lata, hamstring tendon, etc. And due to the loss of ligament strength during grafts survival, the most commonly used allogeneic graft was still patellar ligament [18]. As for this method, the material could be easily drawn, the sequelae could be less and the patella joint pains would be few. The results of this study showed that the anterior knee pain after allogeneic patellar ligament transplantation was significantly relieved when compared with other two groups. However, there was no statistical difference in knee function and stability among three groups, which may be related to the hypoesthesia and the instability of the knee joint caused by saphenous nerve injury. In the experiments, one case of severe infection in alBPB group was significantly improved after the use of hormones, antibiotics, joint cavity drainage. And the knee joint function was in a good recovery in 3 months after operation. The grafts were treated at deep low temperature in the experiments because on it could not only prevent the spread of the diseases and reduce the immune rejection of the grafts, but also avoid the loss of the intensity of the grafts after being treated by rays in this approach [19].

Compared with the experiments of Zheng and others, the innovation of this experiment was that the meniscus injury grading was limited to grade 0 or grade I in inclusion criteria, which could avoid the increase of inflammatory factors in knee joint caused by meniscus injury, and affect postoperative recovery of knee joint, thereby increasing the homogeneity among groups [3, 20, 21]. The surgical approach was performed with an anterior medial inlet, and established the tibial tunnel and femoral tunnel respectively at the origin point of ACL tibia and femur. The location of femoral tunnel seriously affected the success of ACL reconstruction. In a retrospective study in France, it was found that the incorrect location of femoral tunnel accounted for 36% of all the failure cases of ACL reconstruction. Another clinical study of patients with failed ACL reconstruction found that non-anatomical locators of the grafts accounted for 88% of the total failed cases, and femoral tunnels locators created by the tibial tunnel accounted for 83% of the total failed cases. Therefore, anatomical reconstruction was essential for the efficacy of ACL reconstruction [22]. In addition, in this study, we did not completely remove the ligament stump, but retained 7 mm stump. In recent years, a two-year follow-up on 51 patients found that the average expansion of the tibial tunnel after the reconstruction of retaining stump was 25.7%, which was much lower than that of the conventional operation (34%) [4]. Moreover, the stump retention could preserve proprioceptor to the greatest extentin the original ligament, so proprioception of knee joint recovered quickly after the surgery. Lee reported that the proprioception recovery of patients with retention stump after surgery was proportional to the length of stump [23].

The innovation of this research was the comprehensive observation indexes. Because we not only compared the major observation indexes (functional scores and stability and so on of knee joint Lysholm, Tegner and IKDC) in three groups, but also compared secondary observation indexes (the operative time, postoperative fever time, Lachman test, pivot-shift

test and the incidence of adverse events and so on). The shortcomings of this study were insufficient cases and short-time follow-up. And there might be significant differences among three groups in clinical efficacy when thetrial with big sample size and long-term follow-up. In addition, this study may produce a greater selection which will affect the reliability of the results without using randomized double-blind approach.

In conclusion, the reconstruction of ACL via auBPB, auHT and alBPB could get good postoperative knee joint stability and these three methods had their own advantages and disadvantages. We are looking forward to the emergence of new artificial ligaments, which will be able to avoid not only the injuries to patients from autotransplant, but also the immunological rejection and the risks of disease transmission from allogeneic transplantation.

Disclosure of conflict of interest

None.

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