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Single-strand versus double-strand reconstruction of anterior cruciate ligament tear: A short-term comparative study

Abstract

Background: Considering the high prevalence of anterior cruciate ligament (ACL) injuries, several attempts have been made to repair the ligament to bring it closer to the natural anatomy. The use of combined semitendinosus and gracilis tendon grafts (double-strand method) is the more common technique to reconstruct anterior cruciate ligament (ACL). Using autograft of quadrupled semitendinosus (single-strand method) may have the same results. We are comparing these two techniques in ACL reconstruction.

Methods: Patients undergoing ACL reconstruction in a 1.5 years period were divided into two groups of double-strand or single-strand technique, and the results were compared by clinical examinations and Lysholm questionnaire in a 6-months follow-up.

Results: Thirty - nine patients under 40 years that were enrolled, included 19 single- strand and 20 double strand patients. There was no significant difference between the two groups in terms of height, weight, body mass index (BMI). The results of clinical testing, complications, Lysholm and pivot shift stability tests were also identical.

Conclusion: Either single -strand or double-strand autografting, depending on patient's condition and the length and diameter of the graft, may be used for ACL reconstruction with similar final end results.

Keywords: Anterior cruciate ligament, Autografts, Anterior Cruciate Ligament Reconstruction, Hamstring Tendons

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Introduction

Anterior cruciate ligament (ACL) prevents the excessive rotation of tibia and helps tibia to be stable in varus-valgus direction. Two separate bundles of ACL, namely anteromedial (AM) and posterolateral (PL) bundles have been demonstrated based on their insertion on the proximal tibia. However, the original sites of the AM and PL control the role of the bundles in different t ranges of knee motion. The rationale of double-bundle reconstruction is mentioned to be better anatomical groupings of fascicles and fibroblasts involved in reconstruction of ACL[(1)].

ACL is the most important stabilizer of the knee since it is located in the center of the knee. Annually, near 175,000 people suffer damage to the ACL worldwide. The injury is most prevalent in young people (ages 15 to 25 years). A small number of people are able to have natural movement despite damage to ACL. However, if the ligament is not repaired in these cases, it can damage meniscus and cartilage of the knee and secondary osteoarthritis may develop.

In recent decades, the prevalence of knee injuries especially ACL injuries have increased in young people. Hence, in past two decades, the methods for reconstruction of the ACL underwent many developments. Most of the patients should undergo surgery to restore the anatomy and normal function of the knee. Before the surgery, swelling of the knee should be removed and the movement and strength of the muscles should return back to normal range[(1,2)].

ACL surgery is the sixth most common orthopedic surgery worldwide. In early years, a single-bundle method was used to reconstruct the ACL with a 60-70 percent of success. Yet, in a number of patients treated with this method, radiographic changes representing osteoarthritis were reported to develop within 20 years after operation[(2)].

Nowadays, along with the advance in imaging and arthroscopic techniques and finding the exact anatomy of the ACL, it is suggested that ACL reconstruction using double-bundle method would bring the ligament closer to the dynamically and functionally normal state[2]. However, there are not sufficient studies proving the advantages of double-bundle protocol[3-7] and there is no consensus on a best method of reconstruction. The patient's cooperation and the type of rehabilitation after the surgery will affect the outcome of the operation.

As mentioned above, the healthy knee joint is necessary for daily activities; and the knee instability from ACL injuries can result in a high risk of knee osteoarthritis. Hence, suitable treatment of the knee injuries is very important. Reconstruction of the ACL can prevent such problems and is cost-effective[6,7].

In patients with knee injury, an immediate examination provides the most important information. In the acute phase of knee injury, Lachman test is the most reliable clinical evaluation to diagnose the injury of ACL with 95% sensitivity?). Pivot-shift test and Anterior Drawer test are other helpful tests to detect suspected rupture of the ACL. In acute knee injury, performing the Lachman test without anesthesia has a diagnostic accuracy of 68-100 percent, and 90-100 percent when performed under anesthetic[8, 9]. Pivot- shift test examines the instability (giving way), as a significant factor for the determination of knee function[10] (Instability, from damaged ACL, can heighten the future risk for meniscus tear, leading to the sense that the knee is not secure.

Non-surgical treatment for ACL tear is recommended for less physically active people like older, patients with sedentary or non-athletic lifestyles[11,12].

Surgical treatment includes initial reconstruction with autografts, allografts or synthetic materials. There are several surgical techniques to reconstruct ACL including: Extra-articular methods with iliotibial band[13,14], Intra-articular arthroscopic or open surgery[15] In the arthroscopic method, the reconstruction of the ACL can be done using the single- or double-bundle hamstring grafts.

The single-bundle reconstruction protocol has generally focused on the repair of the AM bundle without any repair PL bundle. In double-bundle method, two bone tunnels in tibia and two bone tunnels in femur (total of four bone tunnels) are made at the anatomic insertions of both AM and PL bundles. Nevertheless, double-bundle strategy is more invasive and technically complex compared to single-bundle protocol which uses only two bony tunnels[16-21].

However, recent long-term studies have shown that less than 50 percent of patients undergoing single-bundle reconstruction returned to their previous activity. In addition, in a seven year postoperative follow-up, degenerative changes were seen to develop in knee joint of more than 90% of patients. Therefore, there is a requirement for the development of novel surgical techniques. In some patients including the patients who have multiple injuries in the ligament and patients with partial ACL tears (isolated tear of anteromedial (AM) or posterolateral (PL) bundle), the single-bundle reconstruction may be preferred to other surgical protocols.

ACL consists of two main bundles, hence efforts to reconstruct the ligament through a double-bundle technique have been initiated. Yet, published studies on results of performing such methods are limited or contradictory.

In the single-bundle technique, Hamstring tendon grafts may be double, triple, or quadruple stranded. Most surgeons seem to favour a four strand graft. This can either include a quadrupled semitendinosus tendon, or a doubled semitendinosus tendon combined with a doubled gracilis tendon[22-25].

In this study, a quadrupled semitendinosus tendon was named “single-strand” and a doubled semitendinosus tendon combined with a doubled gracilis tendon was called “double-strand”. Although “single-strand” grafts are comparatively shorter, their diameter has a tendency to be larger than “double-strand” grafts[22]. Accordingly, in the current study, it was attempted to compare the clinical outcomes of the single-strand with. double-strand ACL reconstruction.

Materials and methods

Study design and participants

This study was a randomized double-blinded clinical trial. The ethics committee of Baqiyatollah University of Medical Sciences, Tehran, Iran, gave ethical approval (the Declaration of Helsinki was followed and written informed consent was obtained from each patient prior to the participation).

The Patients who were candidates for ACL reconstruction at the above university from May 2016 to Nov 2018, were enrolled in the study.
Inclusion criteria were as follows: Age from 18 to 45 years, BMI <28, no previous knee surgery, no previous knee fracture, lack of simultaneous damage to the posterior cruciate ligament (PCL) or internal and external lateral ligaments.
At the admission time, physical examinations were done, and a complete medical history was taken from each patient. Routine laboratory tests were performed. After a definitive diagnosis of ligament tear through magnetic resonance imaging (MRI), patients were randomly divided to the single- strand or double- strand groups. Considering similar studies, 20 patients were included to each group.
The hamstring autograft was used in every patient. A diagnostic arthroscopy was performed through anteromedial and anterolateral portals. In cases with damaged meniscus, partial meniscectomy was performed. ACL femoral and tibial footprints were determined. Then, through a 4 cm incision positioned medial to the tuberosity, the hamstring graft was harvested and other graft preparations were done.
After the insertion of the guiding pin, femoral tunnels was created using a drill in to the condyle. The femoral guide was inserted through the low anteromedial portal with arthroscopic view. Efforts were made to place the tip of the guiding pin, inserted through the femoral aiming guide, at the center of the previously marked footprint. The femoral tunnel was created by cannulated drill of the same size as the graft over the guiding pin.
After creating the femoral tunnel, the intra-articular point of the tibial guide was placed at the center of the native tibial footprint of the ACL. After insertion of the guiding pin, a tibial tunnel (that was previously detected during the early diagnostic arthroscopy) was drilled with a reamer of the same size as the graft. The hamstring tendon autografts were passed using retrograde drilling. Then, the prepared grafts were fixed in the femoral tunnels with an end button. Flexion-extension cycles were applied for preconditioning of the grafts. Then, the grafts were fixed in the tibial tunnel. During the mentioned steps, the position of the bundle was repeatedly controlled via arthroscopy. At the end, the Lachman test was done to confirm tension and the surgical wounds were closed with sutures. A knee brace (immobilizer) was applied in full knee extension.
A day after surgery, physiotherapy exercise was started. Partial weight -bearing was started. during the first week after surgery, physiotherapy exercise was done to restore full extension-flexion range of the knee with the help of the healthy foot and performing isometric exercises. Straight leg raising (SLR) was done using the knee brace. After the 2nd to 3rd week, resistance sports including the SLR and knee bending against resistance were started. It was attempted to achieve the range of knee motions to 90 degrees at the end of the second week and full motion b the fourth week. The cane was used for about 3-4 weeks after the surgery.
After four months, if the knee had good stability and without any motion restriction, patients were allowed to run on a treadmill. After 5-6 months, patients were allowed to run slowly. Common sporting activities were allowed if the strength of the muscles was like the healthy knee and if there was no limitation in knee range of motion (ROM). After discharge, the patients were examined once every two weeks after one month, and then monthly over six month period. The results of all clinical examinations were recorded for each patient. In patient follow-up examinations, in addition to the clinical examination, Anterior Drawer and Pivot-shift tests were done and the knee condition was assessed and recorded.
After 6 months, the patients were referred to the clinic, clinical examinations were done and the Lysholm score questionnaire was completed. Lysholm questionnaire is a standard questionnaire utilized to evaluate states of the health, demographic and knee in patients after knee surgery. The data of the clinical examination and the questionnaire were separately recorded for each patient. Finally, the data on both single- strand and double- strand groups were statistically analyzed using SPSS16.
The person who performed the data analysis was not aware of the patient's grouping.

Statistical analysis

The data were analyzed using SPSS version 16 (SPSS Inc., Chicago, IL, USA). A p-value of less than 0.05 was considered significant. The quantitative data were presented as mean ± SD and qualitative data were shown as number (percentage). To compare

the parametric variables between the two groups, Student t-test was used. To compare nonparametric variables between the two groups, Chi-square was used. To investigate the relationship between two quantitative variables, correlation was used.

Results:

39 patients under 40 years were studied, 19 treated with single -stand and 20 with double-strand technique.

In the single-strand group, 13 patients (68.5%) of the patients obtained good to excellent scores from the Lysholm questionnaire and 4 patients (21%) obtained a fair to good score from the Lysholm questionnaire. and 2 patients (10.5%) achieved excellent scores from the Lysholm questionnaire. In the double-strand group, 15 patients (75%) obtained good to excellent score and 5 patients (25%) fair to good score from the Lysholm questionnaire and, no patient had excellent score (Table 1).

Overall, 15 patients (37.3%) of patients, tear in the medial meniscus was encountered and 5 patients (12.2%) tear in the lateral meniscus. In 1 patient 3.4% of all patients, there was a rupture in both menisci. 18 patients (47.1%) of patients, there no meniscus injury was seen (Table 2).

In the single-strand group, the mean age of the patients was 26.4 years and the age range was between 18-34 years. In the double-strand group, the mean age of the patients was 27.1 years and the age range was between 18 to 39 years (Table 3).

Table 1. Comparison of the Lysholm score between patients involved in the single-strand and double-strand surgery groups.

Lysholm score	Excellent	Good	Fair	Total
single-strand surgery group	2(10.5%)	13(68.5%)	4(21.5%)	19 (49%)
double-strand surgery group	0	15(75%)	5(25%)	20 (51%)
Total	2(%5)	28(%71/8)	9(%23/2)	39 (100%)

Table 2. Comparison of the meniscus tear type and Lysholm score between patients involved in the single-strand and double-strand surgery groups.

meniscus tear type and Lysholm score		Excellent	Good	Fair	Total
Single-strand	Medial meniscus	3.3%	17.2%	6.5%	5(27%)
	Lateral meniscus	0	6.9%	8.5%	3(15.4%)
	both	0	3.4%	0	1(3.4%)
	Without tear	6.9%	39.7%	7.6%	10(54.2%)
Double-strand	Medial meniscus	0	18.7%	17.4%	7(36.1%)
	Lateral meniscus	0	10.8%	0	2(10.8%)
	both	0	0	0	0
	Without tear	0	47.5%	5.6%	11(53.1%)

Table 3 Comparison of the age between patients involved in the single-strand and double-strand surgery groups.

age	15-20	21-25	26-30	31-35	36-40	Total
Single-strand	(5%) 2	(23%) 9	(15%) 6	(5%) 2	0	(49%) 19
Double-strand	(2%) 1	(25%) 10	(15%) 6	0	(7%) 3	(51%) 20
total	(7%) 3	(48%) 19	(30%) 12	(5%) 2	(7%) 3	(100%) 39

Of all the patients, 32 patients (82%) were injured from exercise incidences, 6 patients (15%) from occupational accidents and 1 patient (3%) were injured from accidents (Table 4).

Of all patients, only 3.5% had a flexion loss more than 5 degrees, (1 patient in the single-strand group). In the double-strand group, no patient had flexion loss greater than 5 degrees. Of all patients, no patient had extension loss more than 5 degrees.

In the single-strand group, the mean BMI was 23.1. The minimum BMI was 19.1 and the maximum BMI was 27.1. In the double-strand group, mean BMI was 24.6. The minimum BMI was 19.5 and the maximum was 27.6 (Table 5).

The 21 patients (51.2%) of these 39 patients suffered vague knee pain during exercise. 7 patients (17.9%) of all patients suffered proximal tibia pain at the graft site. Of the 39 patients, 6 patients (15.3%) suffered vague knee pain during exercise and proximal tibia pain in the graft site simultaneously. In the single-strand group, 9 patients (20.5%) suffered vague knee pain during exercise. In the single-strand group, 5 patients (12.8%) suffered proximal tibia pain at the graft site. In the double-strand group, 12 patients (30.7%) suffered vague knee pain during exercise. In the double-strand group, 2 patients (5.1%) suffered vague knee pain during exercise and proximal tibia pain at the graft site simultaneously (Table 6).

For all patients, surgery was done during chronic post-traumatic episode (after 8 weeks of trauma). In the single -strand group, the mean time from trauma to surgery was 7.5 months. In this group, the minimum interval was 3 months and the maximum interval was 23 months. In double-strand group, the mean time from trauma to surgery was 7.2 months. In this group, the minimum interval was 4 months, and the maximum interval was 18 months.

The type of meniscus rupture (medial or lateral) had no effect on the Lysholm score obtained from the patients (p = 0.71). The interval between trauma to surgery did not affect the Lysholm score(p=0.6).

Table 4. Comparison of the reasons of ACL tear between patients involved in the single-strand and double-strand surgery groups.

Reasons of ACL tear	Exercise	Occupational accidents	Accident	Total
Single-strand	14 (35.8%)	5 (10.6%)	0	19 (49%)
Double-strand	16 (41%)	3 (7.1%)	1 (2.5%)	20 (51%)
Total	30 (79.8%)	8 (17.7%)	1 (2.5%)	39 (100%)

Table 5. Comparison of the BMI between patients involved in the single-strand and double-strand surgery groups.

BMI	18-20	21-22	23-24	25-26	27-28	Total
Single-strand	2 (5.1%)	6(15.35%)	5(13.2%)	3(7.6%)	3(7.6%)	19(49%)
Double-strand	1(2.5%)	6 (15.35%)	6 (15.4%)	4(10.3%)	3(7.6%)	20(51%)
total	3(7.6%)	12(30.7%)	11(28.6%)	7(17.9%)	6(15.2%)	39(100%)

Table 6. Comparison of the complications after the surgery between patients involved in the single-strand and double-strand surgery groups.

Surgical complications	Vague knee pain	Pain at the graft site	Pain at the graft site and vague knee pain
Single-strand	9(20.5%)	5 (12.8%)	4 (10.2%)
Double-strand	12(30.7%)	2(5.1%)	2(5.1%)
Total	21(51.2%)	7 (17.9%)	۶(۱۵٫۳٪)

Table 7. Comparison of the BMI and Lysholm score between patients involved in the single-strand and double-strand surgery groups.

Type of surgery and Lysholm score		Body Mass Index (BMI)					
		18-20	20-22	22-24	24-26	26-28	Total
Single-strand	Excellent	0	(3.4%)	0	(3.4%)	0	(6.8%)
	good	(3.4%)	(3.4%)	(6.8%)	(10.3%)	(6.8%)	(%31)
	fair	0	(3.4%)	0	(3.4%)	(3.4%)	(10.3%)
Double-strand	Excellent	0	0	0	0	0	0
	good	0	(8.0%)	(10.3%)	(10. %)	(13.7%)	(41.3%)
	fair	0	0	0	(10.3%)	0	(10.3%)
Total		(3.4%)	(18.2%)	(17.1%)	(37.4%)	(23.9%)	(%100)

Table.8 Comparison of the injured body side between patients involved in the single-strand and double-strand surgery groups.

Type of injury	Injured side of the body		
	Left	Right	Total
Single-strand	(48.1%) 9	(51.9%) 10	(49%) 19
Double-strand	(25%) 5	(75%) 15	(51%) 20
Total	(35.4%) 14	(64.6%) 25	(100%) 39

The type of trauma causing ACL rupture had no effect on the Lysholm score obtained from the patients (p = 0.12). BMI had no effect on the Lysholm score (p = 0.4) (Table 7).

The 14 patients (35.4%) of all patients had injury in the left knee. The 25 patients (64.6%) of all patients had injury in the right knee.

In the single-strand group, 9 patients (48.1%) had injury in the left knee. In the single-strand group, 10 patients (51.9%) had injury in the right knee. In double-strand group, 15 patients (75%) had injury in the right knee. In the double-strand group, 5 patients (25%) had left knee injury (Table 8).

The two groups did not differ significantly in terms of mean age (p = 0.26), BMI (p = 0.34) and complications (p = 0.14). Data analysis also showed that there was no significant difference between the two groups in terms of mean interval between trauma and surgery (p = 0.86). The two groups did not differ significantly in terms of mean Lysholm score (p = 0.5). The two groups did not have significant difference in the injured body side (p = 0.80) and cause of injury (p = 0.55). The two groups did not differ significantly in terms of the type of meniscal rupture (p = 0.55).

All patients had ADT (anterior drawer test) with Firm End Point after surgery. None of all patients were positive after the Pivot-shift test. None of all patients complained of giving way after surgery.

Discussion

In this study, the clinical results of ACL reconstruction using single- and double- strand reconstruction methods -19 and 20 patients respectively- were compared together 6 months post-surgery with clinical examination and Lysholm questionnaire.

Arthroscopic approach was the method in all the cases. Although the mentioned approach can lead to suitable outcomes in a majority of patients, there are some patients who are dissatisfied with postoperative outcomes in the short or long terms[26,27]. The dissatisfaction may be due to the fact that the reconstruction of ACL with the mentioned method cannot return the normal

activity of the ACL and causes anatomical changes in the muscles around the knee[28].

The ACL has, naturally, a three-dimensional structure containing multi-bundle fascicules. Recently, numerous laboratory studies have been conducted to clarify the anatomical and biomechanical natural function of ACL[29,30]. Accordingly, if the anatomy of the reconstructed ACL is closer to the natural ligament and causes less anatomical change in the knee, the outcomes of the surgery will be better.

Based on the results of this study, the mean age of the two groups ($p = 0.26$), BMI ($p = 0.31$), affected body side ($p = 0.99$), injury to operation time ($p = 0.7$), cause of injury ($p = 0.56$) and the type of the meniscal tear ($p = 0.53$) were not significantly different. Therefore, the effects of the mentioned factors on the outcomes of the surgery were the same in two groups.

With regards to the role of BMI, obesity may be a risk factor for articular degenerative diseases, that has a greater role comparing to knee mechanical injury[31,32]. In our study, the BMI was same in two groups and had a similar destructive role. BMI was not correlated with length and diameter of the graft. Therefore, it could not be a predictive factor for the length and diameter of the graft.

The main goal of this study was to compare the knee stability after ACL reconstruction using double-strand and single- strand methods. Various methods such as clinical tests (Pivot-shift) and standard Lysholm questionnaire have been used in different studies for such comparison. In the current study, Pivot-shift test and standard Lysholm questionnaire were used for the comparison. The results showed that there was no significant difference in the clinical tests between the two groups. None of the patients complained of knee instability after surgery.

In this study, diameter of the grafts that was used for ACL reconstruction was compared in two groups. Results showed that the graft diameter had no statistically significant difference between two groups. Therefore, in this aspect, the two methods were similar. Our results showed that there was no significant difference between the graft diameter, height, weight, and BMI of the patients in the two single- strand and double- strand groups.

In a two- years follow up study, 160 cases undergoing reconstruction, no significant differences between the results of the two ACL surgical methods were observed[33]. In another study, Julian et al reported results of ACL reconstruction by using either semitendinosus alone (single-strand method) or semitendinosus combined with gracilis (double-strand method). Results showed that using semitendinosus alone reduced length of the graft but has a larger diameter than double-strand graft. Moreover, rapid rehabilitation was shown to be associated with increased radiographic bone tunnel widening[17]. In 2016, Wei et al. showed t a significant correlation between height and tendon diameter as well as weight and tendon diameter in women undergoing ACL repair. However, the results were not significant in men[34]. In 2013, ACL reconstruction were performed on 120 patients using the single-strand or double-strand methods. Results showed that the surgical outcome, Lysholm score, knee stability and anterior laxity had no significant difference between the two groups[35].

As to the limitations of our study, small number of participants, short period of follow-up. not counting for confounding issues such as smoking habits, nutritional status, age and sex differences are worth mentioning. Lack of machine along with manual testing for stability, absence of female participants are some of the other limitation to consider.

Conclusion

Our study showed that there was no significant difference between the graft diameter, height, weight, BMI of the patients ,surgical outcome , Lysholm score, knee stability and anterior laxity whether double or single- strand hamstring autograft is used for ACL reconstruction.

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ETHICS STATEMENT

The ethics committee of the baqiyatallah University of Medical Sciences, Tehran, Iran, approved this study (IR.BMSU.RCT.1397.437).

CONFLICT OF INTERESTS

None declared.

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