ARTHROSCOPY AND SPORTS MEDICINE

Arthroscopic posterior cruciate ligament reconstruction by using hamstring tendon autograft and transosseous screw fixation: minimal 3 years follow-up

Seyed Taghi Norbakhsh · Zohreh Zafarani · Arvin Najafi · Hamidreza Aslani

Abstract

Background The aim of this trial is to prospectively evaluate the outcomes of PCL reconstruction by means of quadruple hamstring tendon autograft with a double-fixation method at minimal 3-year follow-up.

Materials and methods Only patients who underwent PCL reconstruction without any other concomitant injury were included in this study. A hamstring tendon graft is composed of a quadruple-stranded gracilis tendon and semitendinosus tendon about 10 cm in length. An arthroscopic technique via a two incision and a double-fixation method was applied. Clinical evaluations were performed for 52 patients. Clinical assessment of patients included the Lysholm knee scores, International Knee Documentation Committee (IKDC) scores, thigh muscle evaluation, and radiographic investigation.

Results On the Lysholm knee score, 90 % of the patients displayed good or excellent rating in the final assessment. In the IKDC rating analyses, 60 % of the patients demonstrated 3–5-mm ligament laxity. For the IKDC final rating, 81 % were normal or nearly normal. Seventy-nine percent of the cases revealed less than a 10-mm difference in thigh girth between their reconstructed and contra lateral limbs.

S. T. Norbakhsh · Z. Zafarani · H. Aslani (✉)
Shahid Beheshti University of Medical Sciences, Velenjak St, Tehran, Iran
e-mail: arvin.najafi@gmail.com

A. Najafi
Tehran University of Medical Sciences, Tehran, Iran

Conclusion Arthroscopic PCL reconstruction using quadruple hamstring tendon autograft provides acceptable outcomes at a minimum 3-year follow-up. The four-stranded hamstring tendon graft is suitable in graft size and results in minimal harvesting morbidity. We recommend that quadruple hamstring tendon graft be chosen for PCL reconstruction to achieve good ligament reconstruction. A double-fixation method which has been applied in this trial can be used to provide rigid fixation.

Introduction

The posterior cruciate ligament (PCL) acts as the principal restraint of posterior tibial translation at all knee positions; it also has an important role in posterolateral knee stability [1]. According to grade of PCL injury, it may lead to various levels of pain and instability which varies from no interference with lifestyle to complete limitation of daily activities. The incidence of PCL injuries is less than anterior cruciate ligament (ACL) injuries and occurs in approximately 3.4–20 % of all knee ligament injuries [2]. In the past, the importance of PCL injury has been excessively simplified and knee functional disability due to PCL injury has been underestimated. Non-operative management of isolated partial or complete PCL tears lead to short-term satisfactory outcomes and controversial long-term results [3]. Although controversy still remains for the optimal approach of PCL injury, improved outcomes after PCL reconstruction have been reported in recent studies [4, 5]. Since long-term follow-up of patients with non-operative treatment experienced a high ratio of poor functional

outcomes and osteoarthritis [6, 7]. Therefore, in patients with complete PCL tear conservative treatment has not been recommended because of inadequate ligament healing. On the other hand, they are at significant risk of functional joint instability, recurrent pain, and knee joint degeneration [8, 9]. Surgical outcomes of PCL reconstruction are variable and often unpredictable. For better functional recovery after PCL injury, surgical reconstruction is indicated for symptomatic severe posterior knee instability and multiple ligament injuries. As a result of tissue availability and surgical approach simplicity, hamstring tendon autografts were used in this survey for arthroscopic reconstruction of the isolated PCL injury. The single-bundle technique was commonly used for anterolateral bundle of PCL reconstruction because of its larger size and better biomechanical characteristics in comparison with the posteromedial bundle [10–12]. This study prospectively evaluated 52 patients who underwent arthroscopic single-bundle PCL reconstruction with a transcrew fixation method at femoral side to assess patient outcomes, efficacy, and potential complications of arthroscopic PCL reconstruction via hamstring tendon autograft. The hypothesis of the study is that hamstring tendon autograft is an effective, safe, and consequently acceptable option for PCL reconstruction which brings about good ligament reconstruction.

Methods

In a prospective study from 2004 to 2008, PCL reconstruction by means of hamstring tendon autograft was conducted on all of our patients with isolated PCL tear without any concomitant injuries. PCL tear was detected by posterior drawer test, positive posterior sag sign. Posterolateral instability was found with external tibial rotation at 30 and 90°, posterolateral external rotation test, external rotation thigh foot angle test, external rotation recurvatum test, reverse pivot-shift test, and posterolateral drawer test. The PCL tears were confirmed by MRI investigations and diagnostic arthroscopy. Every patient with following medical history was excluded: previous failed PCL reconstruction, abnormal preoperative radiographs, simultaneous meniscectomy, avulsion fracture, malposition of tibia and femoral tunnels, chondral damage, and abnormal contra lateral knee joints. Also, patients with combined ACL and PCL reconstruction or meniscectomy were excluded from this survey. Patients with grade 3 or 4 PCL tear without significant posterolateral lesion fulfilled the criteria for PCL reconstruction. According to mentioned criteria, 52 patients were enrolled in our survey. There were 42 males and 10 females. Clinical characteristics of our patients were shown in Table 1. Arthroscopic method

Table 1 Baseline characteristics of the patients

Characteristics	Value
Patients (n)	52
Male/female (n)	42/10
Age at operation (years)	27 (18–49)
Surgery timing	
3 weeks	12 (23 %)
3 weeks–3 months	8 (15 %)
>3 months	32 (62 %)
Follow-up time (mo)	42 (36–46)

was not performed in patients with acute injuries until the knee restores an approximately good range of motion (ROM) with negligible effusion and pain. All the reconstructions were performed by two orthopedic surgeons by using a unique surgical technique. Outcome evaluations were standardized and performed prospectively to permit the researchers to efficiently appraise the outcomes of the reconstructions.

Surgical technique

After adequate general anesthetization, all of the patients underwent a complete physical examination. Diagnostic arthroscopy was conducted to assess the condition of all the relevant anatomic structures and to estimate the extent of ligament tear and any other associated injuries. A quadruple-stranded graft is prepared using semitendinosus and gracilis tendon.

The purpose of the single-bundle PCL reconstruction was to reproduce the anterolateral part of the PCL. The posterior tibial tunnel opening should exit throughout the posterior tibia within the PCL footprint near the most lateral and distal fibers. The preferred femoral tunnel site of the PCL is placed at point 8–10 mm dorsal to the articular junction at the 0130 h point on the right knees and 1030 h point on the left knees which include the anterolateral fibers of the anatomic footprint. With a graft thickness of 9 mm, a point located at the 10:30 position (right knee) or 1:30 position (left knee) is defined 9–10 mm from the chondro-osseous junction. This places the anterior rim of the femoral tunnel about 6 mm from that junction at the origin of the anterolateral bundle of the PCL. This represents an isometric area for the ligament as a whole. The measured point is marked (darkened) with an electrocautery probe, and the distance is rechecked, the knee is flexed to about 110–120°, and a spinal needle is inserted about 1–2 cm lateral and distal to the high anterolateral arthroscopic portal. After the skin incision has been made for the low lateral instrument portal, a guidewire is advanced to

Fig. 1 Postoperative MRI of the patients who underwent PCL reconstruction demonstrates the precise location of graft and biointerference screw

the target point and drilled through the medial condyle. The tunnel is drilled to the graft diameter with a cannulated reamer (not more than 30 mm). The tunnel inlet is smoothed with a spherical bur (abrader) or bone curette to facilitate graft passage. Choose a Transverse Femoral Index Guide (STRYKER TRANSVERSE DRILL GUIDE) equal to the femoral tunnel and assemble the Transverse Drill Guide. The Transverse Drill Guide is inserted through low anterolateral portal into the femoral tunnel to the desired depth. Threaded Guide Pin (XACTPIN) is drilled from the Medial side through the femur and out the lateral femoral cortex. A Fluted Reamer (5 mm 3-FLUTED ACORN REAMER) is used to drill over the Transverse Guide Pin from medial to lateral to a depth of approximately 10 mm less than the STRYKER BIOSTEON Cross-Pin being used. Attach one end of the FLEXWIRE (Soft Flex® Wire) to the 1.5 × 2.4 mm Stepped Insertion Pin. The next step is to attach the opposite end of the FLEX-WIRE to the 2.7 mm transverse threaded guide pin already positioned in the femur. Pull the threaded guide pin laterally out of the femur, thus pulling the FLEXWIRE through the femur leaving it visible on both sides of the knee. Then the tibial PCL drill guide is passed through the medial instrument portal and positioned at the PCL insertion.

The total graft length should be at least 85 mm and preferably 90 mm. While visualizing the femoral tunnel arthroscopically through the Portals, the surgeon pushes or pulls the FLEXWlRE. With the FLEXWIRE visible distal to the tibial tunnel, the hamstring graft is looped over the cable taking care not to twist the FLEXWIRE or PCL graft. Once the PCL graft is in place, the FLEXWIRE is passed medially and laterally to ensure there is free passage through the transcondylar tunnel and the center of the graft. This should be done minimally to ensure free passage but not to cause abrasion to the graft. Cross pin is passed over the medial end

of the guide pin until the cross pin is seated against the shoulder of the stepped guide pin. After confirmation of femoral graft fixation, the opposite end of the graft is tensioned manually as the knee is manipulated through a series of cycles from full extension to full flexion. The detail of the technique was shown in the video file. With the knee flexed between 90° and 100°, and with anterior drawer on the proximal part of the tibia approximately 15 lbs. of manual force is placed on the PCL graft and it is then fixed with a Stryker biointerference Screw. (Fig. 1).

The main end point of such PCL reconstruction is not only to diminish pain, swelling, and inflammation; but also to restore quadriceps control and re-establish a normal gait. After such a surgical approach, the surgically repaired limb requires to be immobilized in a knee brace and is locked in the full extension position for the first week after surgery, and consequently full weight bearing is permitted as tolerated. A straight-leg raising exercise, quadriceps isometric exercises, and a passive range of motion (ROM) have to be started as soon as possible postoperatively. At 8 weeks after surgery, the protected ROM was progressively increased from 90 to 120° and aggressive hamstring-strengthening exercises to be initiated. Patients usually restore their normal physical activity about 3 months after surgery and light sports activities began at 6 months. Full preinjury sports activities are usually recommended between 9 and 12 months postoperatively once ROM and thigh muscle strength had recovered to practically normal.

Follow-up evaluation

All of these patients were followed up to clinical and radiographic evaluation, such as the presence of any symptoms, a subjective assessment of the success of the procedure, overall activity level, the post operative ROM, the degree of laxity, subject functional evaluation, and radiographic investigations at regular periods. The follow-up studies were performed by the authors and their assistants. All of the researchers and their assistants received a unique protocol in testing methods. The results of such evaluations were recorded according to the guidelines of the international knee documentation committee (IKDC) [13]. Generally final evaluation of the knee function was performed according to the patient's subjective assessment, ROM reported, symptoms suffered, and ligament laxity. The Lysholm knee score was applied to assess subjective symptoms, including presence of a limp, requirement of support, evidence of joint locking, postural instability, joint pain and/or swelling, squatting, and stair-climbing ability [14]. The side-to-side difference at maximal manual exam was used to assess the anteroposterior translation for the degree of ligament laxity. A manual posterior drawer test and a KT-1000 arthrometer (MEDmetric Corporation, San

Diego, CA) were applied to evaluate knee stability. Anterior knee pain and hamstring-area pain were subjectively analyzed by the patients to estimate the donor-site morbidity. The difference in thigh circumference between the reconstructed and contralateral knee at a site 10 cm proximal to the superior pole of the patella was defined as thigh atrophy. The Cybex 340 dynamometer (Cybex, New York, NY) was used to detect any residual thigh muscle deficit between the involved and the contralateral knees after surgery. The peak extension and flexion torques were isokinetically examined at 180°/sec. The side-to-side ratio (peak muscle torque of the reconstructed knee/peak muscle torque of the contralateral knee × 100) in peak muscle torque was applied as the indicative marker for thigh muscle strength.

Statistics analysis

Statistical analysis was performed by an independent statistician who was not associated with the surgical team. The κ^2 test is used to compare the ligamentous laxity, the activity level (level I and II against III and IV), and the IKDC final rating outcomes (normal-nearly normal against abnormal-severely abnormal ratings) between preoperative and last follow-up stage. The unpaired Student t test is applied to compare thigh girth difference (<10 mm vs. ≥10 mm) and Cybex dynamometer study data (>90 % vs. ≤ 90 %). The Mann–Whitney U test was applied to compare Lysholm scores for the preoperative and postoperative assessments. The level of statistical significance is considered as P values < 0.05.

Results

Lysholm knee scores

The Lysholm knee scoring system was applied to assess subjective symptoms. The mean preoperative Lysholm score for 52 knees was 59 ± 10 (range, 45–75); the mean postoperative Lysholm score was 90 ± 7 (range, 74–100). After a minimum of 3 years of follow-up, 22 of 52 patients (42 %) achieved excellent outcomes, and 25 patients (48 %) achieved good outcomes. Of the remaining patients, four patients (8 %) achieved fair outcomes and one patient had poor outcome. A significant difference in Lysholm scores between preoperative and final follow-up evaluations was found ($P < 0.05$).

IKDC evaluation

Activity: IKDC categories were used to analyze activity levels preinjury, preoperative, and at final follow-up examination. At primary history taking, all of the patients

had strenuous or moderate preinjury activity levels. Whereas, at time of operation, only 11 (21 %) of 52 patients stated capability of strenuous or moderate physical activity, on the same time 41 (79 %) could perform light or sedentary activity. However, at final follow-up examination, 42 (81 %) of 52 patients had strenuous or moderate activity, and only ten patients (19 %) were limited to light activity. Patient activity levels thus stated considerable improvement after reconstruction ($P = 0.0001$).

Knee function due to patient subjective evaluation

In comparison with the preinjury condition, 41 patients (79 %) subjectively reported their knee function as normal or near normal.

Symptom: Of 52 patients 47 (90 %) suffered no pain along moderate or strenuous physical activities.

ROM: Eighty-five percent ($n = 52$) of these series experienced full ROM. Furthermore, A 3–5- degree difference in extension or 6–15° deficit in flexion from the contralateral limb was found for seven (13.5 %) of the patients. Three patients (5.7 %) reported severely abnormal knee ROM which was defined as flexion deficit of more than 25°.

Ligament examination

Posterior drawer test and posterior sag testing and KT-1000 arthrometer examination showed that 25 (48 %) of the patients exhibited a 0–2-mm ligament laxity. Seventeen patients revealed a 3–5-mm ligament laxity and ten patients showed a 6–10-mm ligament laxity. We found a statistically significant improvement in postsurgical KT-1000

Table 2 Comparison of posterior displacement by KT-1000 arthrometer findings (side-to-side difference in millimeters) at 89 N of force between preoperatively and at final follow-up

Difference	Preoperatively	Final follow-Up
Posterior drawer test		
Grade I (0–5 mm)	0	41
Grade II (6–10 mm)	0	9
Grade III (11–15 mm)	36	2
Grade IV (>15 mm)	16	0
KT-1000 test for IKDC rating		
Normal (0–2 mm)	0	25
Nearly normal (3–5 mm)	0	17
Abnormal (6–10 mm)	24	10
Severely abnormal (>10 mm)	28	0
Mean ± SD*	12 ± 3.9	3.8 ± 2.3

* $P = 0.0005$ (unpaired Student t test) when compared with preoperative data

scores in comparison with preoperative scores ($P = 0.0005$) (Table 2).

Patellofemoral joint findings

At the final examination, moderate patellofemoral crepitation on extension against slight resistance was detected in six patients (11.5 %), and patellofemoral crepitus with mild pain occurred in five patients (10 %).

Donor-Site morbidity

Seven (14 %) patients complained of moderate tenderness, or numbness around distal hamstring tendon area.

Radiographic analysis

No deteriorated radiographic changes were found in 44 (85 %) patients at the final follow-up examination. Stage I degeneration according to Ahlback classification was noted in eight (15 %) patients. 15 all of these degenerative changes were found in the medial compartment.

Functional test

Functional 1-leg hop test results at the final follow-up examination demonstrated that 39 (75 %) patients hopped ≥90 % of the distance hopped with their healthy limb. Nine (17 %) patients achieved 76–89 % of the distance hopped with their normal leg. Four (8 %) patients attained 50–75 % of the distance achieved by their normal limb.

Overall rating

Before reconstruction, all of 52 patients (100 %) were assessed as abnormal or severely abnormal (grade C or D). In contrast, 42 of the 52 patients (81 %) were rated as normal or nearly normal (grade A or B), and only ten (19 %) were noted as abnormal or severely abnormal at final follow-up examination. In comparison with preoperative data there was a statistically significant progress in final rating of the normal–nearly normal against the abnormal–severely abnormal. ($P < 0.05$).

Thigh atrophy

At 3 years after operation, less than a 10-mm difference in thigh circumference between their involved and healthy limbs was found in 41 (79 %) patients. Cybex studies demonstrated that 44 (85 %) patients achieved 90 % or more recovery in extensor muscle strength of. For flexor muscle strength, 47 (90 %) patients achieved 90 % or more of the normal knee. A statistically significant difference

was found in thigh girth difference, extensor strength ratio, and flexor strength ratio before and after operation at minimum 3-year follow-up. (Table 3).

Complications

No patient experienced any joint abscess or deep wound infection because of the surgical manipulation. None of our patients underwent hardware removal because of the discomfort at the site of tibial or femoral fixation.

Discussion

Many cases of PCL ruptures may be treated completely with suitable conservative management [3, 7]. Shelbourne et al. [3] evaluated 133 patients with isolated PCL injury who underwent an unsupervised rehabilitation protocol and reported that 42 % constantly stated the knee as good or excellent. Shino et al. [7]. assessed 15 patients with PCL injury and found that 73 % were participating in moderate to strenuous physical activities and 53 % of the patients reported an overall IKDC of A or B. Arthroscopic PCL reconstruction has recently increased in frequency, and satisfactory outcomes of arthroscopic PCL reconstruction have progressively increased its frequency [15, 16] but the following controversies still should be considered: use of single or double bundle reconstruction, choice of graft tissue, knee flexion angle when a graft is secured, site of tunnel placements, and fixation technique. However, allograft tissues are not accessible in many countries, and transmission of unknown diseases is considered as a main disadvantage [17, 18]. Patellar tendon–bone autograft is the preferred graft for anterior cruciate ligament (ACL) reconstruction [18, 19] and is commonly used as a graft in patients with PCL ruptures [20]. This graft method has several limitations. The patellar tendon autograft may not be strong enough to sufficiently substitute for the PCL and can be too hard to pass throughout the tunnel when the transtibial tunnel technique is applied. In comparison with patellar tendon the quadriceps tendon autograft is thicker and wider so it can act as an ample source of tendons for ligament reconstruction procedures. The quadriceps tendon–bone construction may lead to a flexible substitute graft for applying in primary and revision ACL and PCL reconstruction [16, 21]. On the other hand, a high prevalence of donor-site pain and graft-site morbidity has been detected when both tendon grafts are applied [22–24]. The use of hamstring tendon autograft has recently become more and more frequent. The quadrupled graft of double loops of semitendinosus and gracilis tendons has better mechanical strength than the bone–patellar tendon–bone complex frequently used in ACL reconstruction procedures

Table 3 Thigh atrophy and muscle strength difference preoperatively and at final follow-up between the operative knee and healthy knee

Thigh muscle parameter	Patient number (preoperative postoperative)	Final preoperative Mean $\pm$ SD (mm)	Follow-up Mean $\pm$ SD (mm)	P value*
Thigh girth difference				
<10 mm	22/41	14.53 $\pm$ 6.74	6.38 $\pm$ 3.74	<0.0005
10–20 mm	18/11			
>20 mm	12/0			
Extensor strength ratio				
>90 %	14/44	71.82 $\pm$ 8.36	89.63 $\pm$ 7.28	<0.0005
80–90 %	10/8			
<80 %	28/0			
Flexor strength ratio				
>90 %	14/47	77.91 $\pm$ 8.56	91.23 $\pm$ 7.84	<0.0005
80–90 %	17/5			
<80 %	21/0			

* Comparison between preoperative and final follow-up data performed by using the Mann–Whitney U test

[25, 26]. The hamstring tendon graft technique results in better initial fixation strength than the patellar tendon graft procedure [27], more compatible with accelerated rehabilitation protocols. Likewise, because of multistranded characteristic of hamstring tendon graft which will be provided a larger surface area, it can promote revascularization [28]. In view of both the availability of tissue and the surgical simplicity of the method, hamstring tendon autografts were applied in these patients with isolated PCL rupture for arthroscopic reconstruction. Before surgery, all of the patients suffered from knee instability with persistent pain, swelling, or giving way during physical activities; hence, they were incapable to return to sports. Our results showed that 87 % of the patients had no pain during moderate or strenuous physical activities after operation. Seventy-nine percent of the patients complained no swelling of the involved knee during moderate or strenuous physical activities. Eighty-one percent reported no partially giving way during moderate or strenuous physical activities. Ninety one percent of the patients had no full giving way for their involved knee during moderate or strenuous physical activities. Eighty-one percent of the patients showed less than grade 1 ligament laxity after reconstruction when measured by KT-1000 arthrometer tests. By use of the hamstring tendon graft, the quadriceps muscle rehabilitation possibly more accelerated to resume the extensor muscle strength as soon as possible. Our trial revealed that 3 years after reconstruction, 89 % of the patients could reach to more than 80 % of their extensor muscle strength, in comparison with the normal limb. No reduction in hamstring muscle strength after rehabilitation program has been found in the literature [29]. A study by Yasuda et al. reported that the graft harvest in the knees with anterior cruciate ligament surgery did not considerably change quadriceps muscle strength, but it did extensively reduce hamstring muscle strength only at first

4 weeks after surgery. Activity-related discomfort at the donor place was seldom restricting. The pain could be resolved throughout 3 months after surgery [30]. In our survey, at 3-year follow-up, 77 % of the patients recovered sufficiently in flexor muscle strength, in comparison with contra lateral side. No morbidity was found in association with harvesting of the hamstring tendon. It seems, however, that a lot of patients reduced their activity level between reconstruction and follow-up, probably explaining the rare incidence of complete restoration of knee function after operation. Many studies displayed that PCL injury is a trigger point of degenerative changes in the knee, primarily involving the medial, patellofemoral, and lateral compartments, respectively. This rate amplifies with length of injury, severity of ligament laxity, and duration of follow-up time [31]. In this trial, only eight (15 %) patients experienced stage I degenerative change according to the Ahlback classification at final follow-up. Multi stranded hamstring tendon grafts have been shown as an outstanding graft choice in patients with PCL ruptures [32, 33]. By means of the hamstring tendon graft method, there is no further incision to be made in the suprapatellar area, which as a consequence improved cosmesis. The tendon graft can also be applied to conduct a single femoral tunnel approach or applied as separate bands in a double femoral tunnel method. On the other hand, earlier rehabilitation programs, in our study, would appear to be easier for the involved knee. In comparison with the patellar tendon–bone graft or quadriceps tendon graft method, the hamstring tendon graft technique prevents a further incision and extensor mechanism troubles, with which patellar pain has been a major problem [16, 24]. In this trial, we have assessed the outcomes of quadruple-strand hamstring tendon graft for PCL reconstruction. Only the patients who underwent arthroscopic reconstruction of isolated PCL injury without any associated injuries were included in this study. The

semitendinosus and gracilis tendon graft is sufficient in terms of graft size, and it has resulted in the least harvesting morbidity.

Conclusion

We recommend that quadruple hamstring tendon graft be chosen for PCL reconstruction to achieve good ligament reconstruction. A double-fixation method by considering our femoral site fixation technique can be used to grant rigid fixation.

Conflict of interest The authors declare that they have no conflict of interest.

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