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Reconstruction of the anterior cruciate ligament: a comparison between bone-patellar tendon-bone grafts and four-strand hamstring grafts

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Abstract

Background: Disruption of anterior cruciate ligament (ACL) is a common ligamentous injury of the knee. The choice of graft for (ACL) reconstruction remains controversial. This prospective, randomized clinical trial aimed to compare clinical results of bone-patellar tendon-bone (BPTB) grafts and four-strand semitendinosus-gracilis (ST) grafts for ACL reconstruction over a 3-year follow-up interval.

Methods: Seventy-one patients with an average age of 29± 4.5yearswere treated for torn ACL between 2008 and 2009. Forty-sixpatients underwent reconstruction with BPTB autograft, and 41 were treated with ST autograft. At the time of final follow-up, 37 patients in patella group and 34 patients in hamstring group were evaluated in terms of return to pre-injury activity level, pain, knee stability, range of motion, IKDC (International Knee Documentation Committee) score and complications.

Results: At 36thmonth of follow-up, 34 (92%) and 28 (82%) patients in BPTB and ST group, respectively had good-to-excellent IKDC score ($p > 0.05$). The activity levels were higher in BPTB group ($p> 0.05$). At 3rd yearof follow up, the Lachman test was graded normal, for 23 (62%) and 11 (32%) patients in BPTB and ST group, respectively ($p=0.019$). Regarding the pivot-shift test, 29 (79%) and 15 (44%) patients in patella and hamstring group, respectively had normal test at the latest follow-up ($p=0.021$).There were no significant differences in terms of thigh circumference difference, effusion, knee range of motion, pain and complications.

Conclusion: The results indicate a trend toward increased graft laxity and pivot-shift grades in patients undergoing reconstruction with hamstring autograft compared with patella tendon. However, the two groups had comparable results in terms of activity level and knee function.

Keywords: Anterior Cruciate Ligament (ACL), Reconstruction, Bone-Patellar Tendon-Bone (BPTB) graft, Semitendinosus-gracilis graft, Outcome.

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Introduction

The Anterior Cruciate Ligament (ACL) is regarded as critical to the normal functioning of the knee (1). Disruption of ACL is a common ligamentous injury of the knee that causes significant disabilities especially among athletes. Strategies exist for patients with this injury are controversial between conservative rehabilitation and reconstruction, and between methods of reconstruction (2).

Reconstruction of the ACL allows the patient to resume sporting activities and delays the onset of osteoarthritis, which is as-

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sociated with loss of meniscal function (3, 4, 5).Currently, ACL reconstruction is most often performed using an arthroscopically assisted technique (6).

For the past three decades, the gold standard in ACL reconstruction has been the patellar tendon graft from the middle third of the patella tendon (7), but increasingly the combined semitendinosus and gracilis tendons (ST) graft has been used. This shift in popularity has occurred for several reasons including, concerns about damaging the knee extensor apparatus, the potential for subsequent patellofemoral joint pain, patella fracture, patella tendon rupture, and infra patella contraction (8).

Potential complications also exist with the hamstring techniques. Tunnel widening and fixation may be more of a problem in this procedure and there have been concerns about how the graft harvest procedure may affect the muscle function of the hamstring (8). Other problems include saphenous nerve injuries and harvest-site hematomas.

Although several studies have published long-term results of ACL reconstructions, the outcomes reported have not consistently demonstrated the superiority of one technique over another. This prospective, randomized clinical trial aimed to compare bone-patellar tendon-bone (BPTB) grafts and four-strand semitendinosus-gracilis grafts for replacement in patients with a complete tear of the ACL. Comparisons were made over a three-year interval and consisted of return to pre-injury level of sporting activity, pain, knee stability, range of motion, IKDC (International Knee Documentation Committee) Score and complications.

Methods

Patients

Between 2008 and 2009, 87 patients (74 men and 13 women) with ACL tearing were selected for the study. Exclusion criteria included previous injury or operation on either knee, a concurrent fracture, osteoarthritis in either knee, or significant injury to other ligament structures (including posterior cruciate ligament, lateral collateral ligament, medial collateral ligament, or posterolateral corner of the knee). The study design was approved by our ethics committee and all patients gave informed consent prior to inclusion in this trial.

This patient population was randomized by a computer-generated list in two groups, regarding the treatment. The first group (Group A; n= 46) was treated with bone patellar bone autograft (BPTB); while in the second group (Group B; n= 41) asemitendinosus-gracilis graft (ST) was used.

The average patients age was 29.4 years (range; 17-43 years).The right knee was injured in 48 patients and the left in 39 patients (Table 1). The time between injury and surgery ranged from 4 weeks to 27 months (median, 11 months), and it was similar for the two groups.

Surgical Technique

All reconstructions were performed by a single surgeon. Patients were initially placed in a program of physical therapy emphasizing techniques to regain motion and decrease swelling preoperatively.

At the time of arthroscopy, the knee was examined, associated joint pathology was documented, and irreparably torn meniscal fragments were removed.

BPTB grafting: The bone-patellar tendon bone graft was constructed from the central third of the tendon of the ipsilateral knee. The graft was 10 mm wide and harvested with 20 to 28 mm of bone from the patella and tibial tubercle. The femoral guide pin (Smith & Nephew, London, England) was placed 5 mm anterior to the posterior cortex to allow for a 1 to 2 mm posterior cortical rim after reaming at the ten-thirty position (for right knees) or one-thirty position (for left knees). The tibial guide pin was placed through the footprint of the ACL adjacent to the anterior horn of the lateral meniscus and the tibial tunnel was reamed. All tunnels were reamed to an appropriate size depending on the width of the autograft bone blocks.

The graft was pulled through the tunnels so that the patellar bone block was within the femoral tunnel and the tibial bone block was within the tibial tunnel. The graft was positioned so that no bone protruded into the joint. An interference-fit screw was used in the femoral tunnel to fix the bone block. Tension was then placed on the distal part of the graft, and impingement was excluded by range of motion maneuvers. Next, the graft was secured under an appropriate tension and at the 30° position of the knee within the tibial tunnel with use of an interference screw.

Semitendinosus-gracilis grafting: The tunnels for the hamstring graft were placed in the same manner as the tunnels for the BPTB graft. A 3-cm longitudinal incision was made over the pesanserinus tendons (anteromedial aspect of the proximal tibia 3 to 4 cm distal to the joint line), and the distal insertion site of the semitendinosus tendons was identified and isolated. A tendon stripper was placed over tendon to detach the muscle. A whip nonabsorbable stitch was sutured to the tendon ends and the graft was quadrupled. The proximal end of the graft was fixed to the lateral-distal aspect of the femur with an Endo Button fixation device. A screw was placed, at the 30° position of the knee under appropriate tension over the hamstring graft, just distal to the tibial tunnel. The tibia was loaded with a maximal posterior force during fixation on the tibial side to minimize graft laxity present at the time of surgery.

Postoperative Rehabilitation

The rehabilitation protocol was identical for both groups with passive range of motion exercises instituted immediately and progression to active closed chain exercises achieved by 6 weeks postoperatively. Patients were allowed full weight bearing 3 weeks postoperatively in a hinged brace and returned to running at 3 months. Return to sports participation was allowed at 6 months.

Follow-up Evaluations

All patients were examined and postoperative data were collected at 3 months, 6 months and 3 years after surgery.

Operation time was recorded during surgery in both ST group and BPTB group. Objective parameters used for evaluation included the presence of effusion, Lachman and pivot-shift testing, KT-1000 arthrometer side-to-side differences, modified IKDC knee function scoresand Tegner activity scores (9).

Ranges of knee motion, locking of the knee, and patellofemoral pain werealso recorded. Quadriceps bulk was measured 20 cm above the joint line and compared with that of the contralateral extremity.

Anterior-posterior knee laxity was recorded by using maximum-manual KT-1000 arthrometer at 20° of knee flexion and with the Lachman test. Grading of the Lachman examination was defined as normal, 1+ (increased excursion with an end point), or 2+ (increased excursion without an end point).Pivot-shift examination was graded as normal, 1+ (mild difference between the knees or glide), 2+ (moderate difference or subluxation), or 3+ (gross subluxation).

Activity level was determined using IKDC preoperatively and at latest follow-up. The Tegner activity scale was used to quantitate patient activity levels before injury and at 3-year follow-up.

Post-operative complications including deep infection, wound infection, patella fracture were recorded at follow up visits.

Three-year follow-up was completed for 71(81.6%) of patients; 37 patients of the first group (BPTB) and 34 patients of the second group (ST).

Statistical analysis

Statistical analyses were carried out using SPSS (SPSS statistic package, version 21.0.0) statistical software. The Pearson Chi-square test and the t-test were used to determine whether there were any significant differences. The level of significance was set at $p< 0.05$.

Table 1. Descriptive data for patients in this study

		Bone-Patellar Tendon-Bone Graft	Semitendinosus-Gracilis Graft
Age	Mean±SD	30.8±4.5	28.2±3.7
	Range	17-43	18-41
Sex	Male	38	36
	Female	8	5
Injured leg	Left	21	18
	Right	25	23

Table 2. The IKDC score*

		Bone-Patellar Tendon-Bone Graft	Semitendinosus-Gracilis Graft
Pre operation	A & B	26(70%)	25(74%)
	C & D	11(30%)	9(26%)
36 month follow up	A & B	34(92%)	28(82%)
	C & D	3(8%)	6(18%)

*There was no significant difference in activity levels between the groups at the preoperative and three-year interval.

Results

There were no significant differences between the 2 groups in the number of meniscal or osteochondral lesions. The mean operative time was 74 min in group A and 62 min in group B (p> 0.05).

At the 36-month follow-up 34 patients (91.9%) in group A and 28 patients (82.3%) in group B had good-to-excellent IKDC score (grade A or B), showing statistically insignificant differences between the two group (p > 0.05), (Table 2).The activity levels as measured with the Tegner scale at the three-year follow-up was a mean of 6 points (range, 3 to 9 points) in the bone-patellar tendonbone group and a mean of 5 points (range, 4 to 9 points)in the semitendinosus-gracilis group (p >0.05).

The mean laxity assessed using a KT-1000 arthrometer improved from 6.4±2.2 preoperatively to 2.1±1.1mm at the last follow-up in group A (p< 0.0001) and from 6.6 mm preoperatively to 3.2mm at the last follow-up in group B.Nonetheless, no statistically significant difference between the two groups was observed (p>0.05). Postoperatively for Lachman test, In BPTB group, 23 patients were graded as normal,11patients were graded as 1+ and 3 patients as 2+; comparing with ST group, including 11 patients graded as normal, 18 patients graded as 1+ and 5 patients graded

Table 3. Lachman Test*

		Bone-Patellar Tendon-Bone Graft	Semitendinosus-Gracilis Graft
Pre operation	Normal	0(0%)	0(0%)
	1+	7(19%)	6(18%)
	2+	30(81%)	28(82%)
36 month follow Up	Normal	23(62%)	11(32%)
	1+	11(30%)	18(53%)
	2+	3(8%)	5(15%)

*There was no difference between the groups preoperatively; however, semitendinosus group had a significant increase in grade at three years.

Table 4. Pivot Shift examination*

		Bone-Patellar Tendon-Bone Graft	Semitendinosus-Gracilis Graft
Pre operation	Normal	0(0%)	0(0%)
	1+	4(11%)	6(18%)
	2+	12(32%)	9(26%)
	3+	21(57%)	19(56%)
36 month follow Up	Normal	29(79%)	15(44%)
	1+	6(16%)	12(35%)
	2+	2(5%)	7(21%)
	3+	0(0%)	0(0%)

*There was no difference the groups preoperatively; however, semitendinosus group had a significant increase in grade at three years.

as +2 , the differences was statistically significant (p=0.019), (Table 3).

Regarding the pivot shift test, there was a statistically significant improvement in the integrity of the ACL in both the groups, and also a significant difference was noted between the two groups (p=0.021), (Table 4).

There were no significant differences with regard to thigh circumference difference, effusion, or range of motion between the 2 groups. At the end of 36 months of follow-up, 12 patients (32.4%) in group A and 16 patients (47.1%) in group B had flexion deficit more than 5˚degree, (p>0.05). Six patients (16.2%) in group A and 4(11.8%) in group B had extension loss more than 5˚degree, (p>0.05).

Five patients (13.5%) in group A, and 4patients (11.8%) in group B showed post-operative complications (p>0.05), (Table 5). Six patients (16.2%) in group A and 4(11.8%) in group B, had mild patellofemoral pain at 3-year follow-up, showing no significant differences between the two group (p>0.05).

Table 5. Reported complications*

	Deep infection	Wound infection	Patella fracture
Bone-Patellar Tendon-Bone Graft	1(3%)	3(8%)	1(3%)
Semitendinosus-Gracilis Graft	2(6%)	2(6%)	0(0%)

*There was no difference between the treatment groups.

Discussion

The BPTB and four-strand hamstring grafts (4SHS) are the most common currently used grafts for ACL reconstruction. Controversy still exists over which one gives the best results. The aim of this article was to compare the effectiveness of these two autografts by comparing the results of specific outcomes in 71 patients.

Our study showed superior results for BPTB graft to hamstring autograft in terms of ligament laxity (as assessed with the KT-1000 arthrometer, Lachman examinations and pivot-shift grades) after 36 months of follow up. Of the prospective studies comparing BPTB and hamstring grafts, some showed the graft materials to have similar laxity values (8, 10-22), and others showed significantly better values for the BPTB grafts (23-27).

In 2002, Shaieb et al (17) reported that 88% of patella tendon reconstructions and 86% of semitendinosus reconstructions had a laxity of <5 mm, based on the results of 33-month follow-up of 46 patients. In our study, the mean laxity improved to 2.1 mm in patella-tendon reconstruction group and to 3.2mm in semitendinosus reconstructions at the 3-year follow-up.

In this study the greater number of normal Lachman tests (23 patients v 11 patients) and normal pivot shift tests (27 patients v 15 patients) in the BPTB reconstructions compared with quadrupled hamstring reconstructions indicates a trend toward increased objective stability with the use of BPTB autograft in treatment of ACL tearing. We think these to be of considerable clinical and biomechanical concern and indicate a tendency toward decreased failure rate in this group of patients.

Our cohort of patients had IKDC scores comparable with those reported by other authors (28). In 2002, Beynnonet al (29). conducted a prospective study of 68 patients treated with ACL reconstruction using either a two-strand semitendinosus autograft or a BPTB autograft and assessing knee function and IKDC score at 3-year follow-up. They reported good-to-excellent IKDC scores in 82% and 86% of patients who had undergone patella-tendon and hamstring reconstructions, respectively. It is in accordance with our series that showed good-to-excellent scores in 92% and 82% of the patella-tendon and semitendinosus group, respectively, at 3-year follow up.

Comparing the IKDC score with objective measurement of ligament laxity, we noted parallel outcomes; objective instrumented laxity showed normal anterior translation in 62% of patellar graft cases vs. 32% in semitendinosus group.

In our study, the patella tendon group had higher postoperative Tegner scores than the hamstring group, which reflects a return to higher activity level. We think that the superior graft stability noted in the patella tendon group affect the activity level; however some studies have found that KT-1000 arthrometer side-to-side differences and objective measurement of knee stability are not directly correlated with knee outcome scores (30,31).

Most of previous studies observed that the extension loss is more common in group treated with BPTB graft and higher incidenceof flexion loss in patient who treated with ST graft (32). In accordance with aforementioned studies, in our study the number of patients with extension loss was more in patellar tendon graft group and the number of patients with flexion loss was more in hamstring graft group, but our results did not reach statistical significance.

In our trial both treatments resulted in similar outcomes with regard to prevalence of knee-locking, ability to weight bearing, squatting, climbing stairs, running and thigh circumference difference. Additionally, these subjective factors do not account for the substantial differences in objective stability measurements between the two groups.

Otero et al (24) noted that although patellofemoral crepitus was more common after BPTB reconstructions (29% in comparison with 19% after hamstring reconstruction), anterior knee pain was nearly three times more common in the hamstring group. It was in contrary to Corry et al (21) study that 31% of their BPTB grouphad kneeling pain after 2 years. The incidence in the hamstring group was only 6% after 2 years, and this was statistically significant. However we failed to identify any statistically significant difference in the patellofemoral pain between the two groups.

Neither group in our study underwent an aggressive postoperative rehabilitation protocol nor running delayed until 3 months postoperatively. This protocol was applied to allow for adequately healing of the hamstring grafts within the bone tunnels while maintaining similarity for both groups .The BPTB graft heals by bone to bone healing in around 6 weeks. The 4SHS graft does heal to bone via Sharpey's like fibers, but this takes around 12 weeks (33-34). In order to allow unrestricted mobilization, the graft fixation must be able to at least withstand the normal forces in the native ACL (approximately 500 N). Blickenstaff et al. (35) and Scranton et al. (36) suggested that care should be taken to avoid overload of hamstring grafts during healing. Therefore it is possible that the conservative rehabilitation program that was used for both groups in our trial adversely affected the results of the hamstring reconstructions.

Two-strand hamstring grafts are generally no longer used and are considered as an inadequate graft and a potential cause of poor results (10, 29, 37). The semitendinosus-gracilis graft technique used in this study was quadruple-looped autograft and although it has stiffness comparable to the natural ACL and to patellar tendon autografts (38-40), but patella tendon group in our study had better laxity values, we felt it is due to different graft fixation techniques. Furthermore the more rapid healing of the bone plugs into the graft tunnels may account in part for the decreased failure rate noted in the patellar tendon group.

One of the main concerns during hamstring graft harvest is the inconsistency of the graft. Congenitally small tendons may not be asuitable graft. Anearly avulsed tendon may also be too short touse (32). Other concerns to surgeons using the hamstring graft include the gradually increasing anterior laxity, the use of the weaker double strand hamstring grafts, the longer healing time and graft fixation difficulties.

Conclusion

Our study shows that BPTB autograft with interference screw fixation has superior results compared with ST reconstructive technique. It has lower grades of laxity and pivot shift tests. However, the two groups had comparable results in terms of activity level, and knee function.

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