Scientific Open Access Journals SOAJ

Journal of Orthopedics and Trauma Research

Research Article Open Access

Revision Anterior Cruciate Ligament Reconstruction: Quadriceps tendon autograft compared with Bone-patellar tendon-bone autograft

Abdel Kader Al Askar*, Ziad El Hajj and Alfred Khoury

Makassed General Hospital, Beirut, Lebanon

***Corresponding author: Abdel Kader Al Askar,**
Email: khattab2013@gmail.com

Received: 25 July 2018; **Accepted:** 05 April 2019; **Published:** 08 April 2019

Abstract

Background: Reconstruction of the anterior cruciate ligament (ACL) is one of the most common surgical procedures. Although primary ACL reconstruction is a successful intervention, success rates still range from 75% to 97%. Several thousand-revision ACL reconstructions are performed annually. The quadriceps tendon is a good viable graft source for revision anterior cruciate ligament reconstruction compared with Bone-patellar tendon-bone autograft.

Objectives: The purpose of this study is to compare knee stability, kneeling pain, harvest site pain, and subjective clinical outcome after revision anterior cruciate ligament (ACL) reconstruction with either Bone patellar tendon bone (BPTB) or quadriceps tendon bone (QTB) autografts.

Methods: This is a retrospective multicenter cohort study conducted in Beirut - Lebanon, at Makassed General Hospital and Lebanese American University- Medical Center that included isolated failure of previous ACL reconstruction in adults (>18 years). Anterior knee pain was assessed clinically. Subjective International Knee Documentation Committee (IKDC) score and Lyshlom Knee Scoring Scale were used for patient-evaluated outcome. Anteroposterior knee laxity was measured with physical examination (pivot and lachman tests).

Results: Between 2012 and 2016, 97 patients underwent ACL revision surgeries. 48 patients underwent ACL revision surgery by using a BPTB graft and 49 patients underwent ACL revision surgery by using a QTB graft. Positive pivot shift test results and positive lachman results were approximately the same for QTB and BPTB groups 12.5% vs. 14.3% for the pivot test (p-value= 0.35), and 18.1% vs. 10.2% for lachman test (p-value=0.38) respectively. Anterior kneeling pain, evaluated by the knee walking ability test, was significantly less in the QTB group, with only 6.1% of patients grading knee walking as difficult or impossible compared with 66.7% in the BPTB Group (p-value<0 .0001). At 1 and 2 years' follow-up, there was no difference between the 2 groups in subjective patient-evaluated outcome. The mean IKDC score was 85.7 (0.2) and 88.6 (0.3) in BPTB and QTB groups, respectively (p-value<0 .0001). The mean Lysholm score was 87.1 (0.3) and 91.9 (0.5) in BPTB vs. QTB groups, respectively (p-value<0 .0001).

Conclusion: The use of the QTB graft results in less kneeling pain, and graft site pain than seen with BPTB grafts; also, subjective outcomes are better in QTB graft than in BPTB grafts. However, similar anterior knee stability is seen. The results of this study show that QTB could be a great option for revision ACL reconstruction surgery.

Introduction

One of the most common surgical procedures is anterior cruciate ligament (ACL) reconstruction, where more than 200,000 ACL tears occurring annually [1-3]. Although this procedure have been considered a successful operation, its success rate is still only 75% to 97% [4-6]. As a result, many revision ACL reconstructions are performed annually and are unfortunately associated with inferior clinical outcomes. In this regard, patients should be appropriately counseled on expectations, goals, and a more gradual, prolonged rehabilitation following revision surgery.

A rigorous and meticulous approach should be utilized for patients after failed ACL reconstruction surgery. Even under the best of circumstances, revision ACL surgery is associated with significantly inferior clinical outcomes relative to primary ACL reconstruction [7-12]. There should be no compromise of preoperative evaluation, technical approach, and postoperative rehabilitation to avoid a catastrophic recurrent failure.

Numerous graft sources for anterior cruciate ligament (ACL) reconstruction have been introduced, including an autogenous bone–patellar tendon– bone (BPTB) graft, a hamstring tendon graft, and allografts. The use of BPTB grafts in ACL reconstruction has been considered a standard procedure during the past decade, sometimes even called the gold standard [13].

The BPTB graft provides rigid bone-to-bone fixation and quick bony healing, which allows accelerated rehabilitation to attain full range of motion (ROM) and muscle strength [14,15]. On the contrary, it is often necessary with tendon grafts to delay mobilization, range-of-motion exercise, and physical therapy for protection of the weak link between the graft and bone tunnel [16]. However, drawbacks associated with complaints at the harvest site, also referred to as donor-site morbidity, have been reported in up to 30% of cases [17].

Meanwhile, an autogenous quadriceps tendon– bone (QTB) graft has been recommended as a reliable alternative graft with reduced donor-site morbidity rates reported by some authors [18,19]. This is in primary ACL reconstruction.

What about revision ACL reconstruction?

The purpose of this study was to evaluate and compare the outcomes of revision ACL reconstruction by using QTB autograft compared to a BPTB autograft.

We hypothesized that a QTB graft would result in similar stability, less knee pain, and greater functional scores compared with a BPTB graft.

Methods

From 2012 to 2016, a total of 97 patients underwent revision ACL reconstruction by using QTB autograft or BPTB autograft.

Inclusion criteria were isolated failure of previous ACL reconstruction in adults (>18 years)

Exclusion criteria were; multiple ligament injuries defined as ACL injuries, in combination with posterior cruciate or collateral ligament injuries, concomitant articular cartilage lesions larger than 2 cm2 with a depth of more than 50%of the cartilage thickness; and meniscal injuries involving more than two-thirds of the meniscus or the need for meniscus repair.

Surgical Technique

Bone grafting: Previous tunnels must be evaluated for enlargement with bone loss that may render them unusable for the revision procedure.

If the tunnels have become significantly expanded, it becomes difficult to achieve rigid fixation because of the size of the bony defect [20]. Expanded but completely malpositioned tunnels may allow for independent tunnels to be drilled in a single stage.

However, expanded but partially malpositioned tunnels present a greater technical challenge for a single-stage procedure, and grafting may be favorable to allow for staged preparation of an anatomically correct tunnel position after osseous consolidation and healing [21].

Once the interference screw is removed from the primary ACL reconstruction, the bony defects should be measured. The bone plug should be 1 mm in diameter greater than the debrided tunnel to accommodate a press fit for the graft within the tunnel. Multiple harvest plugs may be necessary if there is a substantial bony defect.

Bone grafting with crushed, cancellous allograft chips can be difficult, particularly in the femoral tunnel, where gravity and fluid flow frequently cause the graft to fall back into the joint.

A confirmatory CT scan can be obtained at 3 to 6 months postoperatively to confirm excellent incorporation and safe staging of the ACL reconstruction, though the CT scan may be deferred in straightforward cases to avoid further exposure to radiation.

Single-Stage Procedure

If the femoral and tibial tunnels from the previous procedure are acceptable or the previous tunnels are grossly malpositioned such that they can be avoided completely when drilling new tunnels, then the revision ACL reconstruction can be done in a single operation.

Completely inaccurate tunnel placement is commonly seen in vertically malpositioned femoral tunnels prepared with a transtibial technique such that a new anatomic femoral socket can be drilled without risk of convergence with the old tunnel.

If this is the case, the old graft can remain in situ, with the new graft offering additional sagittal and rotational stability to the knee. Partially overlapping tunnels are the most problematic and should be reassessed on a case-by-case basis to determine the need for a single versus staged approach.

Posterior tibial tunnels with significant widening may be best treated with a staged approach rather than accepting significant malposition, whereas anterior but relatively anatomic tibial tunnels with expansion may be effectively managed by filling with a large graft in a single-stage setting.

Step 1: Diagnostic Arthroscopy and Socket Characterization

A thorough examination of the knee under anesthesia should be performed before arthroscopy. The general principles of ACL reconstruction apply to a revision procedure as well.

A thorough debridement is critical for visualization and to the success of the revision ACL reconstruction. Both fixation points of the previous graft should be visualized and debrided to clearly define their location and the fixation hardware.

A cyclops lesion or any residual graft should be thoroughly resected before proceeding with the procedure. The notch should be well visualized, and any hypertrophic scar should be resected. An aggressive prior notchplasty may offer insight into socket malposition and the mechanism of graft failure.

A revision notchplasty may be required, however, to afford sufficient visualization for anatomic socket preparation and in rare cases of a narrow or “A-frame” notch configuration, which may pose a significant risk for notch-graft impingement despite anatomic graft obliquity [21].

Step 2: Hardware Removal

Generally, all loose hardware should be removed regardless of its positioning. Determination of whether secure hardware needs to be removed is related to the position of the tunnels from the previous ACL surgery. If the tunnels from the previous surgery are significantly malpositioned and completely new tunnels can be drilled, we prefer to leave the previous hardware in place.

Unnecessary extraction of these fixation devices can lead to bone voids that can be difficult to fill and may compromise the revision ACL fixation options and pullout strength. If the tunnels are only partially malpositioned or are in the correct position, the fixation devices may need to be removed. Often,bioabsorbable screws can be overdrilled, but nonbioabsorbable screws often must be removed. In most cases, the tibial tunnel is the most problematic tunnel, as these screws more commonly interfere with the revision tunnel and graft fixation.

The femoral tunnel is often very poorly aligned in the vertical/anterior orientation that allows for preparation of an entirely new tunnel in an anatomic location.

Step 3: Tunnel Preparation

Femoral tunnel preparation

The medial aspect of the lateral femoral condyle can be accessed through the AM portal or via a 2-incision technique.

The center of the new femoral tunnel can be localized to the center of the footprint if native ligament footprint margins have been preserved. If these have been obliterated from the previous surgery, referencing of the intercondylar and bifurcate ridges can help to facilitate localization of the native femoral footprint [22].

With a medial portal technique, the knee should be hyperflexed to 120°C before drilling the guide wire to allow for sufficient clearance from the medial femoral condyle and satisfactory graft obliquity. “Half-moon” lowprofile or flexible reamers have been useful to avoid injuring the medial femoral condyle and may be passed in modest knee flexion to improve visualization with femoral socket preparation.

Another option for drilling the femoral tunnel is outside-in drilling using the 2-incision technique. This technique requires the creation of an accessory lateral incision. This technique provides the advantage of drilling tunnels in a more oblique or horizontal orientation and may offer great versatility in avoiding the tunnels from the primary surgery.

Alternatively, the over-the-top technique is a viable “nonanatomic” salvage option when the posterior wall of the previous femoral tunnel is insufficient and has compromised the ability to prepare an independent anatomic femoral tunnel [21]. This technique utilizes the same incision and approach as the outside-in technique. Instead of drilling a femoral tunnel, a small opening is created in the intermuscular septum, and a tract is bluntly dissected to the posterolateral aspect of the intercondylar notch. This area should be decorticated with a rasp to create a bleeding cancellous channel for the graft fixation. The graft should be passed into the groove through the septal hiatus with the assistance of a curved clamp or a tendon passer and fixed proximally with a soft tissue staple or screw-and-post suspensory fixation.

Tibial tunnel preparation

A relatively anatomic intra-articular aperture with modest tunnel widening may be utilized and filled with a graft with a large cross-sectional area in a single-stage approach. A relatively posterior tibial tunnel, as frequently observed with a transtibial technique, may be more problematic.

In the absence of significant tunnel expansion, this tunnel may be avoided by independent preparation of a new tunnel with divergent trajectory toward a more anterior anatomic position within the tibial

ACL footprint. The ACL tibial footprint extends anteriorly to the intermeniscal ligament, which allows for a more anterior position of the new tibial tunnel. In the setting of significant tunnel expansion and slight posterior malposition, a staged approach may be required to avoid tunnel convergence or recurrent malposition

Step 4: Graft Fixation

The fixation sites are the weakest component of the revision ACL reconstruction and are often the cause of early biomechanical failure [21]. The graft fixation site should be assessed for quality of bone and relative size of the graft versus the tunnel diameter to achieve adequate fixation with interference devices. Appropriate fixation may be difficult to obtain if there is bone loss and poor bone stock at the fixation site.

In the absence of significant tunnel expansion and good bone stock, interference screw fixation can be utilized in a manner analogous to primary ACL reconstruction. However, stacked screws or any fixation technique that may compromise graft fixation should not be used to facilitate a single-stage reconstruction at the expense of an increased risk of failure.

As in primary ACL reconstructions,the screw divergence from the tunnel should not exceed 15°C [21]. If bone stock is compromised and the quality of interference fixation is modest, fixation should be augmented with a suspensory device such as a screw-post or ligament button. Combination fixation affords the biomechanical advantages of cortical fixation without the associated concerns of graft toggle in the tunnel.

Postoperative Rehabilitation

All patients were informed about follow-up rehabilitation programs.

The rehabilitation protocol was identical for both groups.

Stage 1 (weeks 1-6)

• Protect ACLR and regain full range of motion

• Stationary bicycle

Stage 2 (weeks 6-12)

• Continue range of motion and begin knee and core strengthening

• Begin stair climber at 6 weeks

• Running may begin at 8-10 weeks

Stage 3 (weeks 12-18)

• Advance strengthening, agility training, plyometrics

• Return to sports at approximatley 6-8 months based on “functional sports assessment

Clinical Assessments

Postoperatively, patients were regularly followed up in the outpatient clinic at 2 weeks, 3 and 6 months, and annually thereafter. Knee stability was examined with the Lachman and pivot-shift tests, which were performed by the senior author.

The Lachman test was graded as 0 (_3 mm), 1_ (3 to 5 mm), 2_ (6 to 10mm), or 3_ (_10 mm). The pivot-shift phenomenon was graded as 0 (absent), 1_ (subluxation), 2_(jump), or 3_ (transient lock).

International Knee Documentation Committee (IKDC) scores and Lyshlom scores were used to evaluate functional outcome.

Statistical Analysis

Results were compared between the BPTB and QTB groups by use of the Mann-Whitney test for Lysholm score, as well as Shelbourne and Trumper score, and an unpaired 2-tailed Student *t* test for demographic data (age, time to surgery, and follow-up period) and laxity assessment.

Differences in Lachman test, pivot-shift test, IKDC, and patient satisfaction scores were analyzed with a _2 test. Statistical analysis was performed by use of SPSS software (version 13.0; SPSS, Chicago, IL).

All tests were performed with a 95% confidence level. The level of significance was set at *P* _ .05.

Results

A 48 pts who had revision ACL reconstruction with a BPTB graft and 49 pts who had revision ACL reconstruction with a QTB graft— were assessed in this study. Demographic data collected were similar for both groups (Table1).

Concomitant Injuries

In total, partial meniscectomy was performed in 20 patients. Operatively, meniscal tears were found in 15 patients in the BPTB group. Of the patients, 13 had meniscal tears. In the QTB group 14 patients were found to have meniscal tears. A statistically significant difference between the groups in concomitant injuries regarding either meniscus tears or chondral lesions was not found (Table 2).

Ligament Stability

Preoperatively, the anterior stability in the BPTB group when examined manually was not significantly different from that in the QTB group.

At the final follow-up, upon Lachman examination, 9 patients had grade 1_ laxity and 2 patients had grade 2_ laxity in the BPTB group

In the QTB group 5 patients had grade 1_ laxity and 1 patient had grade 2_laxity

On the pivot-shift test, in the BPTB group 6 patients showed subluxation (grade 1) and 2 patient showed jump (grade 2) after the operation. In the QTB group 7 patients had grade 1_ pivot and no patients had grade 2_ pivot (Table 3).

Harvest Site Pathology

A total of 32 patients (66%) had complaints of irritation, numbness, or tenderness at the donor site in the BPTB group). In the QTB group 3 patients (6.1%) reported moderate discomfort at the quadriceps tendon graft site (*P* _ .0001) (Table 4) (Figure 1).

Table 1: ACL revision surgery by using BPTB and QTB graft.

	BTB (variable: surg_Graft_2) **(n= 48)**	**Quadriceps** (surg_Graft_2) **(n= 49)**	**P-value**
Age (years)	26.4 (0.9)	27.6 (1.1)	0.38
BMI	25.97 (0.54)	26.10 (0.48)	0.95
Gender			
Male	39 (81.3%)	43 (87.8)	0.40
Female	9 (18.8%)	6 (12.2%)	
Level of sports			
Professional	14 (29.2%)	9 (18.4%)	0.211
Recreational	34 (70.8%)	40 (81.6%)	

Table 2: A statistically significant difference between the groups in concomitant injuries.

	Value
Second surgery associated injuries	
None	70 (72.2%)
Bucket handle medial Meniscus	6 (6.2%)
Lateral meniscus	8 (8.3%)
Medial meniscus	12 (12.4%)
Bucket handle lateral Meniscus	1 (1.0%)
Mean time interval between two surgeries (variables: surg_Date_of_1st_Surgery &surg_Date_of_2nd surgery)	28.5 (24.6)

Table 3: Knee stability.

	BTB (variable: surg_Graft_2) **(n= 48)**	**Quadriceps** (surg_Graft_2) **(n= 49)**	**P-value**
Lachman test			
0	37 (77.1%)	43 (87.8%)	
+1	9 (18.8%)	5 (10.2%)	0.38
+2	2 (4.2%)	1 (2.0%)	
+3	0	0	
Pivot test			
0	40 (83.3%)	42 (85.7%)	
+1	6 (12.5%)	7 (14.3%)	0.35
+2	2 (4.2%)	0 (0.0%)	
+3	0	0	

Table 4: In the QTB group 3 patients (6.1%) reported moderate discomfort at the quadriceps tendon graft site.

	BTB (variable: surg_Graft_2) **(n= 48)**	**Quadriceps** (surg_Graft_2) **(n= 49)**	**P-value**
Surgery pain at donor site			
Very minimal	0 (0.0%)	20 (40.8%)	
Minimal	8 (16.7%)	26 (53.1%)	
Moderate	32 (66.7%)	3 (6.1%)	<0.0001
Severe	8 (16.7%)	0 (0.0%)	

Table 5: IKDC and Lysholm Scores.

	BTB (variable: surg_Graft_2) **(n= 48)**	**Quadriceps** (surg_Graft_2) **(n= 49)**	**P-value**
IKDC score	85.7 (0.2)	88.6 (0.3)	<0.0001
Lysholm score	87.1 (0.3)	91.9 (0.5)	<0.0001

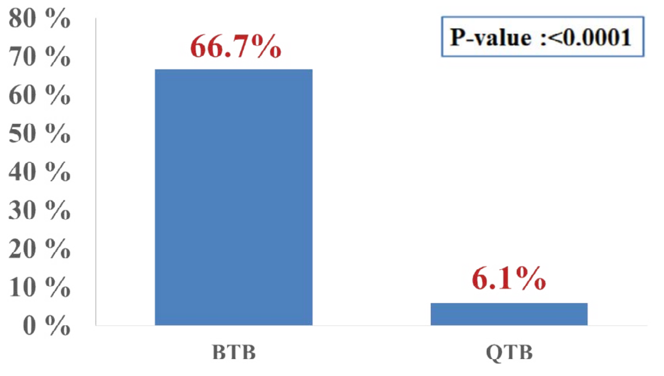

Figure 1: Anterior knee pain.

Overall IKDC and Lysholm Scores

- The IKDC score was 88.6 and 85.7 at in QTB and BPTB groups, respectively .
- The Lysholm score was 91.9 patients and 87.1 at in QTB and BPTB groups, respectively (Table 5).

Discussion

We asked whether QTB grafts lead to similar stability after revision ACL reconstruction compared with BPTB grafts and patients with QTB grafts have less anterior knee pain and a similar clinical performance compared with patients with BPTB grafts.

We intended to maximize the strength of our study with strict inclusion and exclusion criteria to reduce the effects of potentially confounding variables. Our data indicated that the stability of revised reconstructed ACL with QTB grafts was comparable to that of with BPTB grafts.

Grade 0 or 1anterior instability was confirmed in more than 90% of the patients. Han et al.[18] conducted a large retrospective comparative study to compare BPTB and QTB grafts in which 144 patients were enrolled. The stability of the knees with QTB grafts was similar to that inthose with BPTB grafts. The rate of graft failure,defined as the presence of more than 5 mm of anterior laxity, was only 4% in knees reconstructed with QTB grafts.

Gorschewsky et al. [23] suggested similar stability between BPTB and QTB grafts.

In their study 91 of 93 patients receiving QTB grafts showed less than grade 2 instability.

ACL reconstruction by use of BPTB grafts has provided satisfactory outcomes via its bone-tobone healing and proper mechanical properties [24].

However, given the associated morbidity of the BPTB graft [24], such as anterior knee pain, quadriceps or hamstring isokinetic deficiencies, and patellar tendon shortening, alternative grafts, including the QTB graft, have been introduced.

A biomechanical study showed that the ultimate failure load of the QTB complex was 2,173 _ 618 N as compared with 1,953 _ 618 N for the BPTB complex [25].

An electron microscopic study showed that 76% of QTB grafts maintained the original fibril pattern, which may indicate the mechanicalsuperiority of the quadriceps tendon [26].

Adams et al. [27] found that the residual strength of the quadriceps tendon after graft harvest is higher than that of the intact patellar tendon. They suggested that the strength of the extensor mechanism is compromised less by a central quadriceps-free tendon graft harvest than by a patellar tendon graft harvest.

Patellofemoral pain has been reported as the most common and persistent postsurgical complication afterACL reconstruction.

Morbidity at the donor site has been considered to be a contributing factor to patellofemoral pain in autogenous patellar tendon reconstructions [24].

Several studies have suggested thatACL reconstruction using a QTB graft reduces anterior knee pain as compared with that using a BPTB graft [18].

Han et al. [18] found that patients with BPTB grafts had more anterior knee pain than patients with QTB grafts for most activities including sports and work.

Gorschewsky et al. [9] found less donor-site morbidity after reconstruction using QTB grafts compared with BPTB grafts. They therefore stated that QTB-like hamstrings might be a better graft choice for patients with kneeling jobs.

In this study significant differences in symptoms associated with strenuous activities, such as climbing, or daily activities, such as sitting, did not exist between the BPTB and QTB groups.

Shelbourne and Trumper reported that the incidence of anterior knee pain was correlated with failure to gain full extension. They suggested that anterior knee pain may be prevented by obtaining full knee hyperextension through rehabilitation of early knee motion.

Goradia et al. examined factors associated with muscle weakness after ACL reconstruction with autogenous hamstring grafts in 85 patients. They identified a 38% prevalence of patellofemoral pain, which occurred more frequently in patients with quadriceps weakness.

In the Asian population, as in many religious groups worldwide, a major concern regarding harvest-site morbidity is pain on kneeling.

Mastrokalos et al. investigated donor-site morbidity after ACL reconstruction using ipsilateral and contralateral BPTB grafts at a mean follow-up of 39 months. They found that 76.9% of patients with ipsilateral BPTB grafts had complaints during knee walking whereas patients with contralateral BPTB grafts reported kneeling pain at rates of 70.8% and 10.4% for the donor site and reconstructed knee, respectively.

According to Pinczewski et al., kneeling pain wassignificantly increased in knees reconstructed with BPTB grafts compared with those reconstructed with hamstring grafts with an accelerated rehabilitation. At10 years, 27% of patients receiving hamstring grafts and 41% of patients receiving BPTB grafts reported pain with kneeling in the operative knee.

Han et al. [8] reported a low incidence of kneeling pain, 5.5%, using QTB grafts, which was increased by 6-fold in patients with BPTB grafts. In our study 6% of patients with QTB grafts had kneeling pain whereas 66% of patients with BPTB grafts had mild to moderate symptoms, which is in agreement with previous studies.

There were some inherent limitations to this study that warrant review before definite conclusions can be drawn. First, the peak extension torque, used to assess the effect of graft harvest on the recovery of the extensor mechanism, was not evaluated. Therefore, we could not discriminate residual extensor strength between the groups

Second, we could not do accurate functional measurement for knee stability because we do not have the KT arthrometer or other dvices.

Third, the exercise program was not supervised in an educational session. We emphasized the rehabilitation program during the 2-week follow-up visit, and an orthopaedic nurse telephoned the patients to ensure that they were comfortable with rehabilitation at 6 weeks after operation. Therefore, there may have been noncompliance not reported by patients or poor rehabilitation technique. Fourth, we did not found data in the literature comparing QTB and BPTB grafts in revision procedure

Conclusions

A QTB graft appears to be a viable graft for revision ACL reconstruction.

When followed with an accelerated rehabilitation program, revision reconstruction with a QTB graft provided knee stability comparable to a BPTB graft but with less graft site pain than with a BPTB graft.

References

1. Gianotti SM, Marshall SW, Hume PA, Bunt L. Incidence of anterior cruciate ligament injury and other knee ligament injuries: a national populationbased study. J Sci Med Sport. 2009; 12:622-627.
2. Hewett TE, Shultz SJ, Griffin LY. American Orthopaedic Society for Sports Medicine. Understanding and Preventing Noncontact ACL Injuries. Champaign, IL: Human Kinetics. 2007.
3. Parkkari J, Pasanen K, Mattila VM, Kannus P, Rimpelä A. The risk for a cruciate ligament injury of the knee in adolescents and young adults: a population-based cohort study of 46,500 people with a 9-year follow-up. Br J Sports Med. 2008; 42:422-426.
4. Bach BR Jr. Revision anterior cruciate ligament surgery. Arthroscopy. 2003; 19(suppl 1):14-29.
5. Biau DJ, Tournoux C, Katsahian S, Schranz P, Nizard R. ACL reconstruction: a meta-analysis of functional scores. Clin Orthop Relat Res. 2007; 458:180-187.
6. Carson EW, Anisko EM, Restrepo C, Panariello RA, O'Brien SJ, Warren RF. Revision anterior cruciate ligament reconstruction: etiology of failures and clinical results. J Knee Surg. 2004; 17:127-132.
7. Battaglia MJ 2nd1, Cordasco FA, Hannafin JA, Rodeo SA, O'Brien SJ, Altchek DW, et al. Results of revision anterior cruciate ligament surgery. Am J Sports Med. 2007; 35:2057-2066.
8. Battaglia TC, Miller MD. Management of bony deficiency in revision anterior cruciate ligament reconstruction using allograft bone dowels: surgical technique. Arthroscopy. 2005; 21:767.
9. Getelman MH, Friedman MJ. Revision anterior cruciate ligament reconstruction surgery. J Am Acad Orthop Surg. 1999; 7:189-198.
10. Gifstad T, Drogset JO, Viset A, Grontvedt T, Hortemo GS. Inferior results after revision ACL reconstructions: a comparison with primary ACL reconstructions. Knee Surg Sports Traumatol Arthrosc. 2013; 21:2011-8.

11. Johnson DL, Swenson TM, Irrgang JJ, Fu FH, Harner CD. Revision anterior cruciate ligament reconstruction surgery: experience from Pittsburgh. Clin Orthop Relat Res. 1996; 325:100-109.

12. Noyes FR, Barber-Westin SD. Revision anterior cruciate ligament reconstruction surgery: experience from Cincinnati. Clin Orthop Relat Res. 1996; 325:116-129.

13. Fu FH, Schulte KR. Anterior cruciate ligament surgery 1996. State of the art? Clin Orthop Relat Res 1996:19-24.

14. Fineberg MS, Zarins B, Sherman OH. Practical considerations in anterior cruciate ligament replacement surgery. Arthroscopy 2000; 16:715-724.

15. Scheffler SU, Sudkamp NP, Gockenjan A, Hoffmann RF, Weiler A. Biomechanical comparison of hamstring and patellar tendon graft anterior cruciate ligament reconstruction techniques: The impact of fixation level and fixation method under cyclic loading. Arthroscopy 2002; 18:304-315.

16. Paulos LE, Karistinos A, Walker JA. “Criteria”-base rehabilitation of surgically reconstructed and nonsurgically treated anterior cruciate ligament injuries. In: Insall JN, Scott WN, eds. Surgery of the knee. New York: Churchill Livingstone. 2006; 693-714.

17. Pinczewski LA, Deehan DJ, Salmon LJ, Russell VJ, Clingeleffer A. A five-year comparison of patellar tendon versus fourstrand hamstring tendon autograft for arthroscopic reconstruction of the anterior cruciate ligament. Am J Sports Med 2002; 30:523-536.

18. Han HS, Seong SC, Lee S, Lee MC. Anterior cruciate ligament reconstruction: Quadriceps versus patellar autograft. Clin Orthop Relat Res 2008; 466:198-204.

19. Lee S, Seong SC, Jo H, Park YK, Lee MC. Outcome of anterior cruciate ligament reconstruction using quadriceps tendon autograft. Arthroscopy. 2004; 20:795-802.

20. Kamath GV, Redfern JC, Greis PE, Burks RT. Revision anterior cruciate ligament reconstruction. Am J Sports Med. 2011; 39:199-217.

21. Bedi A, Allen AA. Procedure 30: revision anterior cruciate ligament reconstruction. In: Reider B, Terry, MA, Provencher MT, eds. Operative Techniques: Sports Medicine Surgery. Philadelphia, PA: Saunders Elsevier. 2010; 487-514.

22. Bedi A, Altchek DW. The “footprint” anterior cruciate ligament technique: an anatomic approach to anterior cruciate ligament reconstruction. Arthroscopy. 2009; 25:1128-1138.

23. Gorschewsky O, Klakow A, Putz A, Mahn H, Neumann W. Clinical comparison of the autologous quadriceps tendon (BQT) and the autologous patella tendon (BPTB) for the reconstruction of the anterior cruciate ligament. Knee Surg Sports Traumatol Arthrosc. 2007; 15:1284-1292.

24. Noyes FR, Butler DL, Grood ES, Zernicke RF, Hefzy MS. Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. J Bone Joint Surg Am. 1984; 66:344-352.

25. Kartus J, Movin T, Karlsson J. Donor-site morbidity and anterior knee problems after anterior cruciate ligament reconstruction using autografts. Arthroscopy 2001; 17:971-980.

26. Staubli HU, Schatzmann L, Brunner P, Rincon L, Nolte LP. Mechanical tensile properties of the quadriceps tendon and patellar ligament in young adults. Am J Sports Med. 1999; 27:27-34.

27. Lee S, Seong SC, Jo CH, Han HS, An JH, Lee MC. Anterior cruciate ligament reconstruction with use of autologous quadriceps tendon graft. J Bone Joint Surg Am. 2007; 89:116-126.

Citation: Askar AKA, Hajj ZE, Khoury A. Revision Anterior Cruciate Ligament Reconstruction: Quadriceps tendon autograft compared with Bone-patellar tendon-bone autograft. J Ortho Trauma Res 2019; 1:007.