Acta Orthop. Belg., 2022, **88**, 347-354

ORIGINAL STUDY

doi.org/ 10.52628/88.2.7306

Quadriceps tendon vs hamstring autograft in primary ACL reconstruction – a comparative study with minimum two-year follow-up

Maria Victoria Pomenta Bastidas, Sergi Sastre, Josep Maria Segur Vilalta, Jose Rios, Marta Sabater, Dragos Popescu

From the Knee Unit, Hospital Clinic Barcelona, Barcelona, Spain

Recently there has been growing interest in the quadriceps tendon (QUAD) as a valid option for reconstruction of the anterior cruciate ligament (ACLR). The aims of the study is to compare the outcomes achieved in anatomic ACLR involving QUAD *vs*. Hamstring (HT) autografts.

A total of 52 consecutive patients underwent an ACLR, 25 patients with QUAD graft and 27 with HT graft. The same surgical technique, fixation method and postoperative protocol were used in both groups. The following parameters were evaluated: functional status (Lysholm, Tegner, subjective IKDC scores), joint stability (Lachman and pivot shift tests), surgical reoperation rate, complications, degree of satisfaction and return to previous level of activity. Descriptive statistics were analysed using the Student's t-test.

Forty four patients were evaluated (20 QUAD, 24 HT), with a mean follow-up of 27.4 months. Two patients were re-operated in the QUAD group (including one ACL revision), and one patient in the HT group required an ACL revision. There were no significant differences between the two groups in postoperative scores: Lysholm (96.05 *vs.* 96.05), IKDC (86.2 *vs.* 91.2) and Tegner (6 *vs.* 5) scales. The percentage of negative Lachman and pivot shift tests was similar in the two groups (45% *vs.* 50% and 40% *vs.* 45.8%, respectively). There were no significant differences between the groups in the degree of satisfaction (95.8% *vs.* 80%, p = .16) or in the percentage who returned to their previous level of activity (62.5% *vs.* 45%, p = .17).

The use of a QUAD graft in ACL reconstruction leads to similar clinical and functional outcomes to those obtained with HT.

No benefits or funds were received in support of this study. None of the authors have a conflict of interest.

Keywords: anterior cruciate ligament; quadriceps tendon; hamstring tendons; sports medicine; anterior cruciate ligament reconstruction.

INTRODUCTION

Rupture of the anterior cruciate ligament (ACL) is one of the most common sports-related injuries, and it has potentially devastating consequences in both the acute phase and long term. It is estimated that in the USA alone there are 250,000 cases of ACL tearing each year *(1)*. The generally accepted treatment for this injury in active patients is surgical reconstruction of the ACL, the goal of which is to restore knee stability and prevent secondary damage to the meniscus and cartilage.

- Maria Victoria Pomenta Bastidas[1], MD,
- Sergi Sastre[2], MD, PhD,
- Josep Maria Segur Vilalta[2], MD, PhD,
- Jose Rios[3],
- Marta Sabater[2], MD,
- Dragos Popescu[2], MD, PhD.

[1]*Arthroscopy Unit. Hospital General de Catalunya, Sant Cugat del Valles, Spain.*

[2]*Knee & Arthroscopy Unit. Hospital Clinic Barcelona, Spain.*

[3]*IDIBAPS. Universitat de Barcelona, Spain.*

Correspondence : Dragos Popescu MD PhD, Orthopaedic Surgeon. Knee Unit. Hospital Clinic Barcelona, Villarroel 170, Barcelona 08036, Spain. Phone: 932275533.
Email : drdragpopescu@gmail.com

Table I. — Preoperative characteristics of the two groups

Preoperative variables		TOTAL	HT	QUAD	p-value
Nº patients evaluated		44	24	20	
Gender	Female	11 (25%)	8 (33.3%)	3 (15%)	.163
	Male	33 (75%)	16 (66.7%)	17 (85%)	
Age	Mean (SD)	30.50 (2.94)	31.1 (2.60)	30.2 (2.38)	.202
BMI	Mean (SD)	24.33 (1.06)	24.8 (1.2)	24.12 (1.4)	.233
Side of injury	Right	23 (52.3%)	14 (58.3%)	9 (45%)	.477
	Left	21 (47.8%)	10 (41.7%)	11 (55%)	
Time from injury to surgery (months)		10.2 (SD 2.8)	9.8 (SD 2.6)	10.8 (SD 3.1)	.38
Tegner	Median (SD)	3.00 (1.00)	3.00 (1.00)	3.00 (1.00)	.651
Lysholm	Mean (SD)	62.70 (13.43)	62.70 (13.43)	62.70 (13.43)	NA
IKDC	Mean (SD)	66.72 (3.4)	64.8 (2.8)	67.2 (2.4)	.34
Lachman	Grade 0 or 1	5 (11.36%)	3 (12.5%)	2 (10%)	.638
	Grade 2 or 3	39 (88.63%)	21 (87.5%)	18 (90%)	
Pivot shift	Grade 0 or 1	6 (13.7%)	3 (12.5%)	3 (15%)	.323
	Grade 2 or 3	38 (86.3%)	21 (87.5%)	17 (85%)	

Table II. — Intraoperative data for the two groups

Variable		TOTAL	HT	QUAD	p-value
Graft size (mm)	Mean (SD)	8.39 (0.27)	8.39 (0.27)	8.39 (0.27)	NA
	Median (95% CI)	8.00 (8.00; 8.50)	8.00 (8.00; 8.50)	9.00 (9.00; 10.00)	.4
Meniscal injury	No	21 (47.72%)	10 (43.5%)	10 (50%)	.1
	Yes	23 (52.27%)	13 (54.16%)	10 (50%)	
Location of meniscal injury	Internal	14 (60.87%)	8 (61.54%)	6 (60%)	1
	External	9 (39.13%)	5 (38.46%)	4 (40%)	
Meniscal suture		16 (69.56%)	8 (61.54%)	8 (80%)	.23
Meniscectomy		7 (30.43%)	5 (38.46)	2 (20%)	.18
Chondral injury	No	34 (77.27%)	20 (83.3%)	14 (70%)	.16
	Yes	10 (22.73%)	4 (16.7%)	6 (30%)	

The choice of graft for ACL reconstruction remains a topic of debate. Bone-patellar tendon-bone (BTB) and hamstring tendon (HT) autografts are the most widely used *(2)*, and both have demonstrated satisfactory biomechanical properties. However, donor site morbidity remains a problem, and hence the ideal autograft has yet to be established *(3)*. The quadriceps tendon (QUAD) has also been considered

a graft source for ACL reconstruction, although it is much less frequently used. In 2014, Middleton et al. *(4)* surveyed 35 orthopaedic surgeons from more than 20 countries and found that a QUAD autograft was used in only 11% of ACL reconstructions. Nonetheless, there is growing interest in the QUAD as an alternative graft source for ACL surgery, due to low donor site morbidity and the good biomechanical properties achieved *(5)*. Indeed, studies have reported excellent clinical outcomes, as well as low donor site morbidity, when using the QUAD, especially when it is harvested without a bone plug *(5,6)*. The few comparative studies of QUAD *vs.* HT autograft ACL reconstructions report similar functional outcomes *(7-9)*.

The aim of the present study was to compare the clinical and functional outcomes achieved in anatomic ACL reconstructions involving QUAD *vs*. HT autografts, using the same type of femoral and tibial fixation in both cases. Our hypothesis was that the outcomes of ACL reconstructions performed with a QUAD graft would not differ from those involving a HT graft.

MATERIAL AND METHODS

A non-randomized prospective study with patients undergoing ACL reconstruction was performed between October 2014 and July 2016. A total of 52 patients agreed to participate. In our hospital the HT graft is the most commonly used in ACL surgery. The choice of graft was random and depended on the surgeon's judgment and preference. The inclusion criteria were a primary complete tear of the ACL and age less than 55 years. Patients undergoing ACL revision surgery or a concomitant surgical procedure (with the exception of simple meniscectomy or meniscal repair) were excluded from the present analysis. The preoperative patient characteristics collected in both groups were age, gender, body mass index (BMI), time between ACL injury and surgery, and side of injury (Table I). The intraoperative variables analysed included graft size and the presence of meniscal and/or chondral injury (Table II).

The study was approved by our hospital's Research Ethics Committee, and informed consent was obtained from all patients.

All the surgical interventions were single-bundle anatomic ACL reconstructions performed by two surgeons. The same type of femoral and tibial fixation was used in all patients, irrespective of whether the graft was QUAD or HT. For the femur we used a suspensory fixation device, specifically the Endobutton CL (ECL; Smith & Nephew Endoscopy, Andover MA) for HT grafts and the Endobutton CL BTB (ECL-BTB; Smith & Nephew Endoscopy, Andover MA) for QUAD grafts with a bone plug. Tibial fixation in all cases was achieved with a Biosure HA absorbable interference screw (Smith & Nephew Endoscopy) with a diameter 1 mm greater than the diameter of the tibial tunnel. By using the same type of fixation for both kinds of autograft we avoided variations, especially at the femoral level, that could influence outcomes.

The two hamstring tendons (semitendinosus and gracilis) were harvested through an oblique incision in the anteromedial aspect of the tibia, with the help of a tendon stripper (Smith & Nephew Endoscopy). In preparing the graft we sought to achieve a minimum diameter of 8 mm, and thus in many cases it was necessary to triple one or both tendons, obtaining a minimum graft length of 70 mm. The femoral and tibial tunnels were drilled to the same diameter as the graft at the anatomic attachment site in each case. Femoral fixation was achieved with the Endobutton CL (Smith & Nephew Endoscopy, Andover MA). Tibial fixation was performed at 20° of flexion with a Biosure HA absorbable interference screw (Smith & Nephew Endoscopy) with a diameter 1 mm greater than the diameter of the tibial tunnel.

A longitudinal incision approximately 4-5 cm in length was made along the central axis of the QUAD. The tendon was then dissected to harvest a graft with a minimum diameter of 8 mm and length of 60 mm, plus a 20 mm bone plug (Figure 1). While the graft was being prepared we performed complete closure of the QUAD with Vicryl nº 1. The patellar defect was not filled. The femoral and tibial tunnels were drilled at the anatomic attachment site to a diameter 0.5-1 mm greater than the graft diameter. Femoral fixation was achieved with the Endobutton CL BTB (Smith & Nephew Endoscopy, Andover MA). Tibial fixation was performed at 20° of flexion with

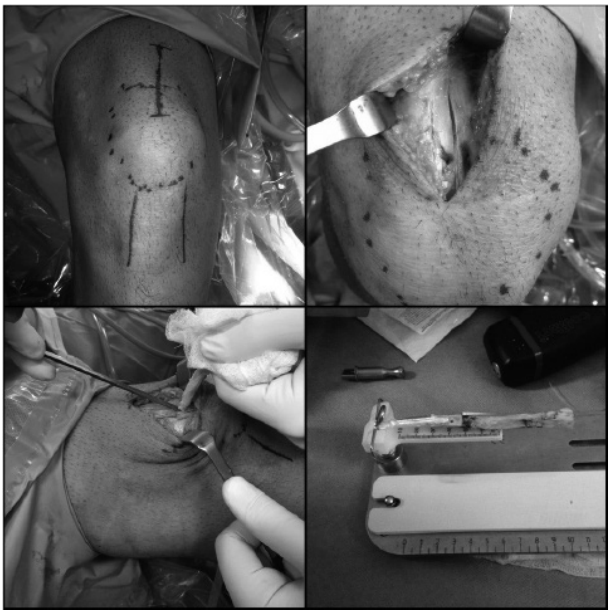

Figure 1. — Intraoperative images of quadriceps tendon graft harvesting and preparation, with the suspensory fixation device at the level of the bone plug.

a Biosure HA absorbable interference screw (Smith & Nephew Endoscopy) with a diameter 1 mm greater than the diameter of the tibial tunnel.

All the patients were hospitalized for 1 day, with isometric quadriceps exercises being initiated within 24 hours of surgery. Passive mobilization of the knee was initiated 24 hours after surgery with the aim of achieving full extension at two weeks and flexion beyond 120° at six weeks. Progressive partial weight bearing with crutches was allowed immediately after the operation. Orthoses were not used except in cases involving meniscal suturing, where they are recommended for the first six weeks with progressive limitation of flexion. Exercises were increased after six weeks, with swimming being allowed at three months, running at four months and contact sports after six months, provided that the patient had recovered strength and proprioception.

Patients were evaluated before and after surgery, with a minimum follow-up of 24 months. All the clinical and functional tests were carried out by a single independent observer (MVP) so as to avoid inter-observer variation.

Knee stability was assessed with the Lachman and pivot shift tests, comparing with the healthy knee and grading it from 0 to 3. For the Lachman test: grade 0 = less than 2 mm; grade 1 = 2-5 mm; grade 2 = 5-10 mm; grade 3 = more than 10 mm. For the pivot shift test: grade 0 = same as the contralateral side; grade 1 = glide; grade 2 = clunk; grade 3 = locking.

The range of joint movement was also assessed, noting any deficit in full extension or in flexion beyond 125°.

Functional assessment was based on the modified Lysholm score *(10)*, the Tegner activity scale score *(11)* and the subjective IKDC score *(12)*.

Patients were asked to rate their satisfaction with outcome on a three-point scale: not very satisfied, satisfied and very satisfied. We also recorded whether patients had been able to return to their previous level of physical activity.

The statistical analysis was performed using SPSS 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Scores on all the functional scales were normally distributed (Shapiro-Wilk test, $p > .05$). The Student's *t* test was used to compare quantitative and qualitative values, while for qualitative variables we applied the chi-squared test. The level of statistical significance was set at .05.

RESULTS

A total of 44 patients were evaluated, with a mean follow up of 27.4 months (SD 3.2). The ACL reconstruction in these patients involved a QUAD graft in 20 cases and a HT graft in 24. The two groups did not differ significantly on any of the preoperative (Table I) or intraoperative (Table II) parameters assessed.

The results for both the clinical (Lachman and pivot shift tests) and functional (IKDC, Lysholm and Tegner scores) assessment showed a significant post-operative improvement in all patients. Importantly, comparison of the two groups revealed no significant differences in their clinical and functional outcomes (Table III). Only one patient in the HT group had a 5° extension deficit. There were no significant differences between the groups in terms of post-operative satisfaction (95.8% *vs*. 80%,

Table III. — Clinical and functional outcomes in the two groups

Postoperative variables		TOTAL	HT	QUAD	p-value
Tegner	Median (SD)	6.00 (1.00)	6.00 (1.00)	5.00 (1.00)	.11
Lysholm	Mean (SD)	96.05 (2.17)	96.05 (2.17)	96.05 (2.17)	NA
IKDC	Mean (SD)	88.32 (3.46)	91.23 (3.54)	86.28 (6.8)	.38
Lachman	Grade 0	21 (47.72%)	12 (50%)	9 (45%)	.36
	Grade 1	19 (43.22%)	10 (41.67%)	9 (45%)	
	Grade 2	4 (9.1%)	2 (8.33%)	2 (10%)	
Pivot shift	Grade 0	19 (43.22%)	11 (45.83%)	8 (40%)	.24
	Grade 1	21 (47.72%)	11 (45.83%)	10 (50%)	
	Grade 2	4 (9.1%)	2 (8.33%)	2 (10%)	
Return to previous level of activity	No	20 (45.45%)	9 (37.5%)	11 (55%)	.17
	Yes	24 (54.55%)	15 (62.5%)	9 (45%)	
Satisfaction	Not very satisfied	5 (11.36%)	1 (4.17%)	4 (20%)	.162
	Satisfied	25 (56.82%)	14 (60.9%)	11 (55%)	
	Very satisfied	14 (31.82%)	9 (39.1%)	5 (25%)	

p = .16) or in the percentage who returned to their previous level of activity (62.5% *vs*. 45%, p = .17).

Regarding complications, one patient in the QUAD group required revision surgery of the donor site, although the suturing was intact. Patellar fracture following a QUAD graft has been reported in the literature, but there were no such cases among our patients. No other wound complications was found in neither of the groups.

Two patients (one in each group) required ACL revision surgery, with the injury in both cases occurring while playing sport.

DISCUSSION

The most important finding of the study was that no differences were found in functional and clinical outcomes depending on whether a QUAD or HT autograft was used for ACL reconstruction.

Only a few studies have compared the use of QUAD vs. HT graft in ACL reconstruction surgery. In a recent comparative study of 86 patients with a mean follow-up of 3.6 years, Cavaignac et al.[8] reported equal or better clinical and functional outcomes with QUAD reconstructions. However, this was a retrospective study and the authors do not report preoperative data verifying that the two study groups were homogeneous. In both groups of patients, interference screws were used for both femoral and tibial fixation. Lee et al. *(7)* conducted a retrospective comparative study of 96 patients. It should be noted, however, that patients in the HT group underwent ACL reconstruction via a medial port with a double bundle graft, whereas the procedure in the QUAD group involved a single-bundle transtibial reconstruction. The authors observed similar clinical and functional outcomes in the two groups, although flexor muscle strength recovery was better in the QUAD group at both one-year and two-year follow up. In contrast to these findings, Sofu et al. *(9)*, in a retrospective study of 44 patients, reported better graft stability when HT were used for ACL reconstruction, although the Lysholm score was similar in both the QUAD and HT groups. Our functional results differ from those of this later study, but are similar to those

reported by other authors *(7,8)*. Slone et al. *(13)*, in a systematic review of 14 studies that fulfilled strict inclusion criteria, reported good stability outcomes, range of motion, functional outcomes and overall satisfaction in patients undergoing ACL reconstruction with a QUAD autograft. In addition, the rate of complications appeared to be lower in QUAD graft than in HT graft reconstructions. In another systematic review, Mulford et al. *(14)* concluded that the QUAD graft is a promising alternative for ACL reconstructions, although they acknowledge that further randomized studies are needed to determine whether it is as good or better than other autografts.

The growing interest in use of the QUAD autograft is due in part to studies demonstrating its good biomechanical properties. In the majority of these studies the tendon is harvested with a bone plug, as was the case in our patients. Compared with the patellar tendon, the QUAD has been found to offer greater thickness and stiffness and increased resistance to tensile load *(15-17)*. Sasaki et al. *(18)* reported a biomechanical cadaveric study comparing QUAD with HT autografts. The two grafts achieved similar results in terms of restoring anterior tibial translation and rotatory instability, and they did not differ significantly under any of the experimental conditions tested.

There is some controversy regarding harvesting of the QUAD autograft. Although the recommendation is to harvest the graft from the thicker medial portion of the QUAD *(19,20)*, the majority of studies do not support harvesting a full-thickness graft *(7,8,21)*. By preserving the deepest layer of the QUAD one avoids opening the suprapatellar bursa, thus reducing the risk of fluid leakage during the arthroscopy and of possible postoperative adhesions *(8)*. In our study we did harvest the full width of the QUAD, thus ensuring a thicker and more resistant graft. Fluid leakage can be avoided provided the tendon is correctly closed. We observed no cases with adhesions or limited mobility after using this method of graft harvesting.

To our knowledge, this is the first comparative study of QUAD vs. HT autografts for ACL reconstruction to have used suspensory femoral fixation in both groups. Suspensory femoral fixation is rarely used with a bone plug, but we opted to do so in order to homogenise the groups, rather than use an interference screw in the QUAD group and Endobutton in the HT group, as in the case of studies published to date. There is scant literature regarding the use of this type of fixation device. In a biomechanical comparative study of suspensory femoral fixation for grafts with and without a bone plug, Miyatake et al. *(22)* reported similar elongation in both cases. However, stiffness was inferior when the fixation device was connected to a graft with a bone plug. In light of their results the authors recommended that patients in whom suspensory fixation has been used with a bone plug should not perform vigorous exercise in the early period of rehabilitation following ACL reconstruction. Taketomi et al. *(23)*, in a clinical study of 34 patients who underwent ACL reconstruction with a BPTB graft and suspensory femoral fixation (ECL-BTB), reported bone integration into the femoral socket in all cases. The mean distance of bone plug migration, when observed, was 0.4 mm, less than that described for soft tissue grafts *(24)*, and it had no clinical repercussions. The authors suggest two possible explanations for why bone plug migration was shorter in ACL reconstructions with a BPTB graft than in soft tissue grafts: one is that the bone plug is harder to move (due to greater friction) when it is placed in a rectangular as opposed to a cylindrical socket; the other is that integration into the femoral socket occurs more quickly with a bone plug than with a tendon. Irvine et al. *(25)* compared graft-tunnel motion for ACL reconstructions involving BPTB and HT autografts, with suspensory femoral fixation being used in both groups. They found no differences between the two groups at 6 weeks or at 1 year, thus questioning the idea that BPTB grafts heal more quickly than do soft tissue grafts. Kondo et al. *(26)* compared the use of two Endobutton devices (the ECL and the ECL-BTB) in ACL reconstructions using HT autografts. They found that use of the ECL-BTB significantly shortens the operation time, and that there were no differences in clinical and functional outcomes.

Among patients included in the present study there were no complications related to the use of this type of fixation device for the bone plug. Our

sole recommendation is that the femoral tunnel should be drilled to a diameter 0.5-1 mm greater than the diameter of the graft so as to facilitate entry of the bone plug into the tunnel. This is especially relevant in the case of an anatomic reconstruction and helps to avoid possible complications such as bone plug fracture or migration, or migration of the fixation device, etc.

This study has a number of limitations. First, patients were not randomly assigned to one of the two groups. Second, the sample size may have been too small to detect differences between the groups. Third, stability was assessed subjectively (Lachman and pivot shift tests) rather than through more objective methods (KT1000). Finally, muscle strength in the operated leg was not tested using isokinetic dynamometry.

CONCLUSION

Despite these limitations, the results of this study suggest that ACL reconstruction with a QUAD autograft leads to similar clinical and functional outcomes to those achieved with a HT graft. The quadriceps tendon should be considered a valid alternative for ACL reconstruction.

REFERENCES

1. Moses B, Orchard J, Orchard J. Systematic review: Annual incidence of ACL injury and surgery in various populations. Res Sports Med 2012;20:157-179.
2. Duquin TR, Wind WM, Fineberg MS, Smolinski RJ, Buyea CM. Current trends in anterior cruciate ligament reconstruction. J Knee Surg 2009;22:7-12.
3. Shelton WR, Fagan BC. Autografts commonly used in anterior cruciate ligament reconstruction. J Am Acad Orthop Surg 2011;19(5):259-264.
4. Middleton KK, Hamilton T, Irrgang JJ, Karlsson J, Harner CD, Fu FH. Anatomic anterior cruciate ligament (ACL) reconstruction: a global perspective, Part 1. Knee Surg Sports Traumatol Arthrosc 2014;22(7):1467-1482.
5. DeAngelis JP, Fulkerson JP. Quadriceps tendon: a reliable alternative for reconstruction of the anterior cruciate ligament. Clin Sports Med 2007;26(4):587-596.
6. Geib TM, Shelton WR, Phelps RA, Clark L. Anterior cruciate ligament reconstruction using quadriceps tendon autograft: intermediate-term outcome. Arthroscopy 2009; 25(12):1408-1414.
7. Lee JK, Lee S, Lee MC. Outcomes of anatomic anterior cruciate ligament reconstruction: bone-quadriceps tendon graft versus double bundle hamstring tendon graft. Am J Sports Med 2016;44(9):2323-2329.
8. Cavaignac, Coulin, Tscholl, Nik Mohd Fatmy, Duthon, Menetrey J. Is Quadriceps Tendon Autograft a Better Choice Than Hamstring Autograft for Anterior Cruciate Ligament Reconstruction? A Comparative Study With a Mean Follow-up of 3.6 Years. Am J Sports Med 2017;45(6):1326-1332.
9. Sofu H, Sahin V, Gürsu S, Yıldırım T, Issın A, Ordueri M. Use of quadriceps tendon versus hamstring tendon autograft for arthroscopic anterior cruciate ligament reconstruction: a comparative analysis of clinical results. Eklem Hastalik Cerrahisi 2013;24(3):139-143.
10. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 1982;10(3):150-154.
11. Tegner Y, Lysholm J. Rating systems in the evaluation of knee liga- ment injuries. Clin Orthop Relat Res 1985;198: 43-49.
12. Hefti F, Muller W, Jakob RP, Staubli HU. Evaluation of knee ligament injuries with the IKDC form. Knee Surg Sports Traumatol Arthrosc 1993;1(3-4):226-234.
13. Slone HS, Romine SE, Premkumar A, Xerogeanes JW. Quadriceps tendon autograft for anterior cruciate ligament reconstruction: a comprehensive review of current literature and systematic review of clinical results. Arthroscopy 2015;31(3):541-554.
14. Mulford JS, Hutchinson SE, Hang JR. Outcomes for primary anterior cruciate reconstruction with the quadriceps autograft: a systematic review. Knee Surg Sports Traumatol Arthrosc 2013;21(8):1882-1888.
15. Woo SL, Hollis JM, Adams DJ, Lyon RM, Takai S. Tensile properties of the human femur-anterior cruciate ligament-tibia complex. The effects of specimen age and orientation. Am J Sports Med 1991;19(3):217-225.
16. Harris NL, Smith DA, Lamoreaux L, Purnell M. Central quadriceps tendon for anterior cruciate ligament reconstruction. Part I: Morphometric and biomechanical evaluation. Am J Sports Med 1997;25(1):23-28.
17. Stäubli HU, Schatzmann L, Brunner P, Rincón L, Nolte LP. Mechanical tensile properties of the quadriceps tendon and patellar ligament in young adults. Am J Sports Med 1999;27(1):27-34.
18. Sasaki N, Farraro KF, Kim KE, Woo SL. Biomechanical evaluation of the quadriceps tendon autograft for anterior cruciate ligament reconstruction: a cadaveric study. Am J Sports Med 2014;42(3):723-730.
19. Park SE, Ko Y. A novel graft preparation technique of the quadriceps tendon for arthroscopic double-bundle anterior cruciate ligament reconstruction. Arthrosc Tech 2013; 31;2(3):e197-200.
20. Potage D, Duparc F, D'Utruy A, Courage O, Roussignol X. Mapping the quadriceps tendon: an anatomic and morphometric study to guide tendon harvesting. Sure Radiol Anat 2015;37(9):1063-1067.
21. Lund B, Nielsen T, Faunø P, Christiansen SE, Lind M. S. Quadriceps tendon a better graft choice than patellar

tendon? a prospective randomized study. Arthroscopy 2014;30(5):593-598.
22. Miyatake S, Kondo E, Tohyama H, Kitamura N, Yasuda K. Biomechanical evaluation of a novel application of a fixation device for bone-tendon-bone graft (EndoButton CL BTB) to soft-tissue grafts in anatomic double-bundle anterior cruciate ligament reconstruction. Arthroscopy 2010;26(9):1226-1232.
23. Taketomi S, Inui H, Nakamura K, Yamagami R, Tahara K, Sanada T, Masuda H, Tanaka S, Nakagawa T. Secure fixation of femoral bone plug with a suspensory button in anatomical anterior cruciate ligament reconstruction with bone-patellar tendon-bone graft. Joints 2016;28;3(3):102-108.
24. Mae T, Kuroda S, Matsumoto N, Yoneda M, Nakata K, Yoshikawa H, Shino K. Migration of EndoButton after anatomic double-bundle anterior cruciate ligament reconstruction. Arthroscopy. 2011;27(11):1528-1535.
25. Irvine JN, Arner JW, Thorhauer E, Abebe ES, D'Auria J, Schreiber VM, Harner CD, Tashman S. Is There a Difference in Graft Motion for Bone-Tendon-Bone and Hamstring Autograft ACL Reconstruction at 6 Weeks and 1 Year? Am J Sports Med 2016;44(10):2599-2607.
26. Kondo E, Yasuda K, Miyatake S, Kitamura N, Tohyama H, Yagi T. Clinical comparison of two suspensory fixation devices for anatomic double-bundle anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2012;20(7):1261-1267.