E. Witvrouw · J. Bellemans · R. Verdonk
D. Cambier · P. Coorevits · F. Almqvist

Patellar tendon vs. doubled semitendinosus and gracilis tendon for anterior cruciate ligament reconstruction

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Abstract In a prospective study on ACL reconstruction we treated 17 patients with a “central third-bone-patellar tendon-bone” autograft (PT group) and 32 patients with a doubled semitendinosus/doubled gracilis autograft (HS group). Patients were reviewed at 6 weeks, and at 3, 6, and 12 months postoperatively and the groups compared. Up till 6 months, the KT-1000 side-to-side difference was significantly greater in the HS group ($P<0.05$) and at 6 and 12 months isokinetic hamstrings strength was lower ($P<0.05$). No significant differences were noted at any stage with respect to quadriceps strength, functional scores, range of motion, or swelling.

Résumé Dans une étude prospective de la reconstruction du ligament croisé antérieur nous avons traité 17 patients avec un transplant rotulien os-tendon-os (PT Groupe) et 32 patients avec une autogreffe de tendon gracilis doublé et semitendineux doublé (HS Groupe). Les Patients ont été examinés à 6 semaines, et à 3, 6, et 12 mois postopératoires. Jusqu’à 6 mois, les KT-1000 comparatifs des deux cotés étaient significativement plus grands dans le groupe HS ($P<0.05$) et à 6 et 12 mois la force isocinetique des tendons ischio jambiers était inférieure ($P<0.05$). Aucune différence notable n’a été notée en ce qui concerne la force du quadriceps, les scores fonctionnels, la mobilité ou les épanchements articulaires.

Introduction

At present, autogenous grafts remain the most popular form of intra-articular replacement of the ACL. For autografts, the continuing controversies surround the choice of graft with patella tendon vs. hamstring tendon being the most contentious. Only a few studies have been published comparing the two techniques [2, 4, 5, 7, 8, 11]. We therefore designed a prospective study on the use of the patellar tendon vs. semitendinosus and gracilis tendon in ACL-deficient patients. The purpose of this study was to evaluate the clinical outcomes of the two different tissues used for reconstruction in similar patient populations using a standardised surgical technique, rehabilitation scheme and method of follow-up.

Materials and methods

From 1996 to 1998 17 patients with a central third-bone-patella tendon-bone autograft (PT) reconstruction were compared with 32 patients who underwent a doubled semitendinosus/doubled gracilis autograft (HS) reconstruction after they had met extensive inclusion criteria.

All patients had symptomatic instability that was primarily caused by a loss of the ACL and all had a 3+ to 4+ gross pivot shift and 3+ Lachmann. No statistical differences in preoperative laxity between both groups were observed. Patients with a chondral damage, previous meniscectomy or ACL repair, collateral ligament injuries, excision of more than one-third of one meniscus, an abnormal radiograph, or an abnormal contralateral knee joint were excluded, as were those patients who had associated posterior tibial translation or posterolateral rotatory instability, or did not wish to participate in a research program. No patients were involved in claims for workers’ compensation and none were professional athletes.

In the PT group there were seven women and ten men and the average age was 24.3 (18–63) years. In the HS group there were 15 women and 17 men and the average age was 24.6 (17–34) years.

Operative technique. In the patellar tendon group a 10-mm-wide bone-patellar tendon-bone autograft was used, with 7-mm interference screw fixation both at the femoral and tibial side. In the hamstring tendon group a doubled semitendinosus + gracilis autograft was inserted, with endobutton fixation on the femoral side and use

E. Witvrouw (✉) · D. Cambier · P. Coorevits
Department of Rehabilitation Sciences and Physiotherapy,
Faculty of Medicine, Ghent University Hospital,
De Pintelaan 185, 9000 Ghent, Belgium
e-mail: erik.witvrouw@rug.ac.be
Tel.: +32-9-2402609, Fax: +32-9-2403811

J. Bellemans
Department of Orthopaedics, University Hospital of Leuven,
Leuven, Belgium

R. Verdonk · F. Almqvist
Department of Orthopaedic Surgery,
Physical Medicine and Rehabilitation, Ghent University Hospital,
Ghent, Belgium

of a bicortical screw and spiked washer on the tibial side. In both groups the surgery was performed as an arthroscopic procedure and all grafts were fixed with the knee in 30° of flexion. In all cases a standard lateral and superior notch plasty was performed.

The postoperative care and rehabilitation protocols were the same in both groups. The knees were placed in a postoperative splint in full extension. Active flexion and immediate weight bearing were allowed from the first postoperative day. An accelerated rehabilitation program was undertaken using closed kinetic chain exercises and proprioceptive training. By 6 weeks, jogging in straight lines, swimming, and cycling were permitted. After 12 weeks general strengthening exercises were continued and agility work and sport-specific activities were encouraged. Return to competitive sport involving jumping, pivoting, or sidestepping was prohibited until 9 months after reconstruction, but with variable patient compliance.

Preoperatively and 6 weeks, 3, 6, and 12 months postoperatively all patients were evaluated on several outcome measurements as thigh atrophy, knee swelling, and range of motion.

Instrumented knee laxity measurement was performed by an experienced physical therapist for both groups using the KT-1000 arthrometer (MEDmetric, San Diego, Calif., USA), using a 15- and 20-pound load. Each measurement was performed three times, and the average value was used for statistical purposes. Results of the instrumented laxity measurements were recorded as the difference between the injured and uninjured knees.

Extensor and flexor muscles strength was evaluated with a Cybex 350 isokinetic dynamometer at 6 and 12 months postoperatively. The peak torque quadriceps and flexor strength of the oper-

ated knee was measured and related to the opposite normal side at 60 (three repetitions) and 240 (five repetitions) deg/s.

Patients completed the Lysholm knee score [10] and Tegner scale [17] to document subjective symptoms and activity level. A Kujala score [9] was used to determine the amount of patellofemoral complaints. Each patient formed functional testing including hoptests but only at 6 and 12 months postoperatively.

Statistical evaluation was done using the S.A.S. (Statistical Analysis System) statistical software package (SAS Institute, Cary, N.C., USA). Analysis of variance for repeated measures with the Tukey multiple-comparison test was used to calculate differences between each group. Using the chi-square test we calculated significant differences between the number of patients in each category based on sex, side of injury, level of sports activity, or interval from injury to surgery. The minimum level of significant was $P=0.05$.

Results

In relation to the preoperative parameters the two groups were comparable (Tables 1, 2, 3, 4). There were no significant differences regarding age, sex, side of injury, or interval from injury to surgery ($P>0.05$). As for the range of motion and the circumferential measurements (Table 1) no significant differences could be detected at

Table 1 Differences in range of motion measurements, swelling of the knee joint and thigh atrophy of the patella tendon group (PT, $n=17$) and the hamstring-semitendinosus group (HS, $n=32$; means $\pm$ SD)

	Preoperative		6 weeks postop		3 months postop		6 months postop		12 months postop	
	PT	HS	PT	>HS	PT	HS	PT	HS	PT	HS
Flexion deficit (°)	7.4 (5.7)	9.9 (6.3)	18.6 (14.4)	28.9 (15.3)	7.8 (6.8)	11.4 (5.3)	5.3 (6.7)	8.9 (4.5)	4.2 (1.2)	6.9 (3.6)
Extension deficit (°)	1.8 (2.4)	1.1 (3.1)	3.1 (2.8)	3.1 (3.6)	2.1 (2.6)	1.1 (2.7)	2 (2.3)	1.2 (2.7)	1.2 (1.8)	0.4 (1.6)
Swelling difference (cm)	0.3 (0.7)	0.3 (0.6)	1.6 (0.4)	0.7 (0.9)	0.7 (0.9)	0.6 (0.6)	0.7 (0.4)	0.2 (0.5)	0.1 (0.5)	0.1 (0.4)
Atrophy thigh (cm)	1.3 (2.2)	0.9 (1.3)	2.5 (1.3)	2.2 (1.8)	1.7 (1)	2.1 (1.1)	1.4 (1.4)	2 (1.6)	1.1 (1.6)	1.3 (1.6)

Table 2 Side-to side differences in KT-1000 arthrometer (mm) measurements (means $\pm$ SD) in the patella tendon group (PT, $n=17$) and the hamstring-semitendinosus group (HS, $n=32$) at the different evaluation periods

	Preoperative		6 weeks postop		3 months postop		6 months postop		12 months postop	
	PT	HS	PT	>HS	PT	HS	PT	HS	PT	>HS
15 pounds	4.9 (3.6)	4.2 (3.3)	0.5 (1.9)*	1.4 (2.5)	0.6 (2.2)*	1.6 (1.9)	0.9 (3.6)*	2.1 (3.3)	1.1 (3.4)	1.4 (3.1)
20 pounds	5.7 (3.7)	4.6 (3.5)	0.7 (2.1)*	1.4 (2.5)	0.7 (1.8)*	1.8 (2.6)	0.9 (3.7)*	2.2 (3.5)	1.2 (3.6)	1.4 (3.3)

* Significant difference between both groups ($P<0.05$)

Table 3 Results of the Lysholm, Tegner, and Kujala scales and of the functional hoptest (means $\pm$ SD) in the patella tendon group (PT, $P=17$) and the hamstring-semitendinosus group (HS, $n=32$) at the different evaluation periods

	Preoperative		6 weeks postop		3 months postop		6 months postop		12 months postop	
	PT	HS	PT	>HS	PT	HS	PT	HS	PT	>HS
Lysholm	64.6 (16.9)	69.8 (17.1)	64.8 (13.5)	61.1 (17.9)	83.2 (16.9)	81.8 (17.7)	88.9 (9.1)	84.9 (14.6)	93.5 (8.7)	90.2 (13.1)
Tegner	2.6 (1.9)	2.7 (1.6)	1.3 (0.7)	0.9 (1.1)	3.2 (0.9)	2.9 (1)	3.6 (0.8)	4 (1.2)	4.8 (1.1)	4.3 (1.5)
Kujala	67 (20.1)	69.1 (18.3)	46.5 (13.4)	43.1 (13.2)	68.5 (13.4)	65.7 (14.7)	81.1 (12.5)	78.3 (17.2)	89.5 (13.4)	88 (14.5)
Hoptest (%)	75.5 (22.9)	73 (21.6)	—	—	—	—	71.1 (29.4)	81.1 (15.3)	91.8 (19.9)	114.5 (15.7)

Table 4 Results of the isokinetic strength measurements: the injured leg in percent of the contralateral leg (means $\pm$ SD) in the patella tendon group (PT, $P=17$) and the hamstring-semitendinosus group (HS, $P=32$) at the different evaluation periods

	Preoperative		6 months postop		12 months postop	
	PT	HS	PT	>HS	PT	HS
Quadriceps 60°/s	41.3 (15.2)	40.5 (14.4)	59.5 (19.6)	62.4 (11.1)	76.8 (15.3)	83.5 (16.7)
Quadriceps 240°/s	66.8 (11)	71.7 (16.8)	67.4 (18.6)	74.8 (16.7)	79.9 (17.2)	85.4 (15.7)
Hamstrings 60°/s	64.4 (14.3)	76.9 (12.3)	89.8 (12.3)*	65.9 (14.2)	98.2 (11.2)*	88.7 (14.6)
Hamstrings 240°/s	88.6 (18.1)	88.6 (15.3)	95.4 (18.7)*	82.2 (18.9)	92.6 (11.7)	85.8 (14.9)

* Significant difference between both groups ($P<0.05$)

any of the different evaluation periods ($P>0.05$). With an exception for the PT group at 6 weeks, the average differences in knee swelling between the injured and uninjured side were less than 1 cm at all evaluation periods in both groups.

The results in terms of knee stability measured with the KT-1000 arthrometer are reported in Table 2. At 6 weeks, 3 months, and 6 months postoperatively the HS group revealed a statistically greater knee laxity compared to the PT group, for as well the 15- and 20-pound load. Looking at the results of the knee arthrometer 1 year postoperatively, the average value for the PT group was not significantly different from the average value of the HS group, at any of the loads.

No significant differences were found for the Lysholm, Tegner, and Kujala scores at any of the evaluation moments ($P>0.05$; Table 3).

At 6 and 12 months postoperatively, the HS group showed a significantly lower mean isokinetic peak torque value at 60°/s, compared to the PT group (Table 4). Looking at the isokinetic peak torque results at 240°/s, a significantly lower value was also observed for the HS group at 6 months postoperatively ($P=0.044$).

Concerning the Quadriceps function, no significant differences at either velocity were found between the mean isokinetic peak torque value at any evaluation period ($P>0.05$; Table 4).

Discussion

In this study the laxity of the hamstring tendon graft was found to be inferior to that of the patellar tendon graft. This is in agreement with previous clinical findings [5, 8, 12]. The results also correspond very well with the results of Steiner et al. [16] on human cadavers. In this study the patellar tendon grafts were found to have a closer-to-normal ACL stiffness than did the hamstring grafts. The strength of the hamstring grafts was comparable to that of their control ACL specimens, but the stiffness (29 N/mm) was less than half of the controls. In contrast, ACL reconstructions using patellar tendon grafts were notable for their close-to-normal ACL stiffness (46–50 N/mm).

Other studies [2, 11] did not find a significant difference in knee laxity comparing these grafts. However, de-

spite the similar stability measurements in hamstring and patellar tendon grafts found in their study, both Marder et al. [11] and Aglietti et al. [2] described a trend toward better stability using patellar tendon grafts. It is well known that the stability after reconstruction is not only determined by the choice of graft but also by the fixation method [9]. Since several studies have shown [11, 13, 16] that the tensile strength of the double semitendinosus and gracilis tendon is comparable to, or higher than the patellar tendon, or normal ACL, the weakness of the HS graft in terms of stability may be due to the initial fixation.

Since the initial fixation is less stable with the hamstring graft [16], the accelerated rehabilitation used in our study might be partly responsible for the greater knee laxity in the HS group. Therefore a less accelerated rehabilitation regimen is perhaps to be advised. Especially, full extension immediately after surgery may not be advisable.

It may be of interest to identify in which way the observed differences in stability have functional implications. With respect to the activity level, functionality, and morbidity, the scores showed satisfactory recovery and patient subjective assessment in both groups without significant difference. This is in accordance with previous studies where there were no difference in functional outcome between patients with patellar tendon grafts and patients with hamstring grafts [2, 5, 11]. The comparable functional scores and a low correlation of knee laxity with functional scores may confirm that laxity is not directly linked to clinical outcome. Therefore, it is tempting to state that knee laxity results are of minor importance in the functional outcome of ACL patients. However, one must have in mind that the differences in laxity in our study are rather small, and ultimately we have no knowledge of the long-term effects of the greater knee laxity.

Isokinetic testing revealed significant differences in hamstring peak torque at 6 months and 1 year postoperatively. This finding must be considered important since the hamstring muscles are substantial to the stabilization of the knee joint and function as a restraint to excessive (anterior) joint motion. The observed difference in isokinetic flexor strength could be expected since harvesting a graft consequently leads to a decrease in muscle strength. Marder et al. [11] also found a significantly

lower hamstring peak torque strength whereas Aglietti et al. [2] did not observe any difference by comparing patients with patellar tendon grafts and hamstring grafts. A possible difference in rehabilitation program might be responsible for this observed difference. In our study, and in the study of Marder et al. [11], no isokinetic training at slow speeds [15] was performed, while it is unknown whether these exercises were performed in the study of Aglietti et al. [2]. Furthermore, there might also be a difference in the type of athletes treated in the different studies.

Regarding isokinetic extensor strength no significant differences could be found. This confirms what has been seen in other reports [2, 11, 14], that patellar tendon harvesting does not weaken the extensor strength. Rubinstein et al. [14] proved that the morbidity of a patellar tendon graft harvesting appears to be of short duration and is reversible.

Limitation of extension used to be a problem [1, 3], but with the current rehabilitation using early mobilisation and passive full extension, the problem is minimized. We found no cases with more than 5° of extension loss irrespective of group.

The results of our study indicate that satisfactory results after reconstruction of the anterior cruciate ligament using patellar tendon or hamstring tendons are obtained. We observed however that using double semitendinosus/gracilis tendons, the anterior knee laxity was inferior up till 6 months postoperatively and the isokinetic peak flexion strength lower. Interestingly, these findings did not result in differences in functionality.

References

1. Aglietti P, Buzzi R, D'Andria S (1992) Long-term study of anterior cruciate ligament reconstruction for chronic instability using the central one-third patellar tendon and a lateral extra-articular tenodesis. *Am J Sports Med* 20:38–45
2. Aglietti P, Buzzi R, Zaccherotti G, De Biase P (1994) Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. *Am J Sports Med* 22:211–218
3. Aglietti P, Buzzi R, Giron F, Simeone AJV, Zaccherotti G (1997) Arthroscopic-assisted ACL reconstruction with the central third patellar tendon. *Knee Surg Sports Traumatol Arthrosc* 5:138–144
4. Aune AK, Ekland A, Cawley PW (1998) Interference screw fixation of hamstrings vs. patellar tendon grafts for ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 6:99–102
5. Corry IS, Webb JM, Clingeleffer AJ, Pinczewski LA (1999) Arthroscopic reconstruction of the anterior cruciate ligament, a comparison of patellar tendon autograft and four-strand hamstring tendon autograft. *Am J Sports Med* 27:444–454
6. Feagin JA, Curl WW (1976) Isolated tear of the anterior cruciate ligament: 5-year follow up study. *Am J Sports Med* 4:95–100
7. Harter RA, Osternig LR, Singer KM (1989) Instrumented Lachmann tests for the evaluation of anterior laxity after reconstruction of the anterior cruciate ligament. *J Bone Joint Surg [Am]* 71:975–983
8. Holmes PF, James SL, Larson RL, et al (1991) Retrospective direct comparison of three intraarticular anterior cruciate ligament reconstructions. *Am J Sports Med* 19:596–600
9. Kujala UM, Jaakola LH, Koskinen SK, Taimela S (1993) Scoring of patellofemoral disorders. *Arthroscopy* 9:159–163
10. Lysholm J, Gilquist J (1982) Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med* 10:150–154
11. Marder RA, Raskind JR, Carrol LM (1991) Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction. Patellar tendon versus semitendinosus and gracilis tendons. *Am J Sports Med* 19:478–484
12. Otero AL, Hutcheson L (1993) A comparison of the double semitendinosus/gracilis and central third of the patellar tendon autografts in arthroscopic anterior cruciate ligament reconstruction. *Arthroscopy* 9:143–148
13. Rowden NJ, Sher D, Rogers GJ (1997) Anterior cruciate ligament graft fixation: initial comparison of patellar tendon and semitendinosus autografts in young fresh cadavers. *Am J Sports Med* 25:472–478
14. Rubinstein RA, Shelbourne KD, VanMeter CD, McCarroll JC, Rettig AC (1994) Isolated autogenous bone-patellar tendon-bone graft site morbidity. *Am J Sports Med* 22:324–327
15. Sherman WM, Plyley MJ, Vogelgesang DA (1981) Isokinetic strength during rehabilitation following arthrotomy. *Athl Training* 16:138–143
16. Steiner ME, Hecker AT, Brown CH, Hayes WC (1994) Anterior cruciate ligament graft fixation; comparison of hamstring and patellar tendon grafts. *Am J Sports Med* 22:240–247
17. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. *Clin Orthop* 198:43–49