Patellar Tendon or Semitendinosus Tendon Autografts for Anterior Cruciate Ligament Reconstruction?: A Prospective Randomized Study with a Two-Year Follow-up

Lars Ejerhed, Jüri Kartus, Ninni Sernert, Kristina Köhler and Jon Karlsson

Am. J. Sports Med. 2003; 31; 19

0363-5465/103/3131-0019$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 31, No. 1

Patellar Tendon or Semitendinosus Tendon Autografts for Anterior Cruciate Ligament Reconstruction?

A Prospective Randomized Study with a Two-Year Follow-up

Lars Ejerhed,*† MD, Jüri Kartus,* MD, PhD, Ninni Sernert,* Kristina Köhler,* and Jon Karlsson,‡ MD, PhD

*From the *Department of Orthopaedics, Norra Älvsborg/Uddevalla Hospital, Trollhättan/Uddevalla, and the ‡Department of Orthopaedics, Sahlgrenska University Hospital, Göteborg, Sweden*

Background: There are well-known problems with the use of bone-patellar tendon-bone autografts for anterior cruciate ligament reconstruction, especially in terms of donor site morbidity. Hamstring tendon grafts have been increasingly used as an alternative, but there are very few controlled studies comparing the methods.
Hypothesis: Use of semitendinosus tendon grafts will cause less donor site morbidity and result in better knee-walking ability.
Study Design: Prospective randomized clinical trial.
Methods: Seventy-one patients who had a unilateral anterior cruciate ligament rupture underwent arthroscopic reconstruction with interference screw fixation and use of either bone-patellar tendon-bone or semitendinosus tendon graft. Outcome assessment was performed by physiotherapists not involved in the patients' care.
Results: At the 2-year follow-up, no differences were found in terms of the Lysholm score, Tegner activity level, KT-1000 arthrometer side-to-side laxity measurement, single-legged hop test, or International Knee Documentation Committee classification results. The knee-walking test was rated difficult or impossible to perform by 53% of the bone-patellar tendon-bone group and by only 23% of the semitendinosus graft patients, a significant difference.
Conclusions: The semitendinosus tendon graft is at least an equivalent option to the bone-patellar tendon-bone graft for anterior cruciate ligament reconstruction, and we recommend its use.

Use of the central third of the patellar tendon with bone blocks as a graft for arthroscopic reconstruction of the ruptured ACL has become a standard procedure during the past decade. Several studies have reported the outcome of such surgery as good and reproducible.[5,15,26] However, there are obvious problems with this method, especially in terms of donor site morbidity.[14,18,29,34] Anterior knee pain, disturbances in the sensitivity of the knee, and kneeling discomfort are common problems. An alternative graft option is also required in the event of the need for revision surgery.

In a dissection study, we have previously reported on the opportunity to harvest bone-patellar tendon-bone grafts without damaging the infrapatellar branches of the saphenous nerve.[16] In a clinical setting, use of this graft harvesting technique reduced the area of lost knee sensitivity, but some patients still reported problems in kneeling and walking on their knees.[17]

During the last decade, hamstring tendon graft in the form of tripled or quadrupled semitendinosus or doubled semitendinosus/gracilis tendons has become an increasingly used alternative for ACL reconstruction. However, there are very few controlled studies comparing these two options.[1,8,23,25]

† Address correspondence and reprint requests to Lars Ejerhed, MD, Department of Orthopaedics, Uddevalla Hospital, SE-451 80 Uddevalla, Sweden.
No author or related institution has received any financial benefit from research in this study. See "Acknowledgments" for funding information.

The aim of this prospective randomized study was to compare the outcome of ACL reconstruction with subcutaneously harvested bone-patellar tendon-bone graft[17] and with tripled or quadrupled semitendinosus tendon graft. The hypotheses were that the use of semitendinosus tendon grafts in ACL reconstruction will cause less donor site morbidity in terms of subjective anterior knee pain and result in the patient having better ability to walk on his or her knees. Furthermore, the use of semitendinosus tendon grafts will render good knee stability and functional outcome to the same extent as do bone-patellar tendon-bone grafts.

MATERIALS AND METHODS

Patients

Patients with a symptomatic unilateral chronic ACL rupture were prospectively randomized for reconstruction with either ipsilateral bone-patellar tendon-bone graft (BTB group) or with the ipsilateral tripled or quadrupled semitendinosus tendon graft (ST group). The randomization was accomplished by using sealed envelopes. The Human Ethics Committee at the Medical Faculty at Göteborg University approved the study and all subjects gave their informed consent.

Surgical Technique

One senior surgeon experienced in use of both techniques performed all of the reconstructions. In the BTB group, the arthroscopic transtibial technique[27] and interference screw fixation[21] were used during the initial procedure. The mid-third of the patellar tendon was harvested through two 25-mm long vertical incisions: one over the apex of the patella and the other just above the tibial tubercle. The graft was retrieved subcutaneously under the paratenon with the aim of protecting the infrapatellar branches of the saphenous nerve and leaving the major part of the paratenon intact, as previously described by Kartus et al.[16] The defects of the patella and the proximal tibia were not bone grafted. The proximal bone block was sized to 9 mm and the distal bone block to 10 mm. The bone tunnels were prepared in a standard transtibial fashion. A 7-mm and a 9-mm Acufex "silk" interference screw (Acufex Microsurgical, Inc., Mansfield, Massachusetts) were used on the femoral and tibial side, respectively (Fig. 1).

In the ST group, the graft was harvested through a 3-cm oblique incision over the pes anserinus. The tendons were palpated and the sartorius fascia was incised parallel to the fibers of the fascia just above the thicker and more distally inserted semitendinosus tendon. After the vinculae had been cut under visual control, the tendon was harvested with a semiblunt, semicircular open tendon stripper (Acufex Microsurgical, Inc.). The tendon was prepared for a tripled or quadrupled graft, depending on its length. The minimum accepted length for the final graft was 7 cm. Two No. 5 nonresorbable Ticron sutures (Sherwood Medical, St. Louis, Missouri) were used as the lead sutures at the distal and proximal ends. Resorbable No. 1 Vicryl sutures (Ethicon, GmbH, Norderstedt, Germany) were used for the modified

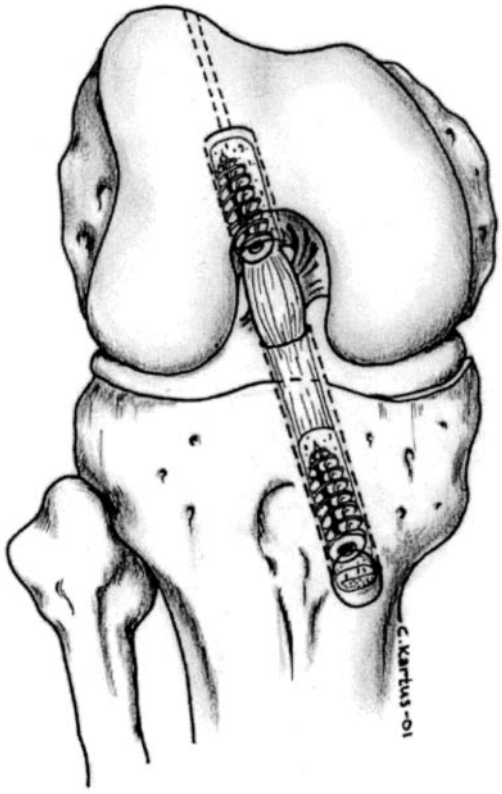

Figure 1. In the BTB group, a 7-mm and a 9-mm interference screw were used on the femoral and tibial side, respectively.

baseball stitches at the distal and proximal ends of the semitendinosus tendon graft. The bone tunnels were prepared in the same transtibial fashion as in the BTB group. A 7-mm soft-threaded RCI interference screw (Smith & Nephew, Inc., Andover, Massachusetts) was used on both the femoral and tibial sides (Fig. 2).[6] In both groups, after the femoral screw had been inserted, firm traction was applied to the graft during the insertion of the tibial screw, with the patient's knee in hyperextension.

Clinical Assessments and Follow-up

Two independent physiotherapists, not involved in the patients' rehabilitation, performed all of the pre- and postoperative assessments. The manual Lachman test (graded as 0, +1, +2, or +3) and the KT-1000 arthrometer (MEDmetric Corp., San Diego, California) were used for the assessment of stability.[7] The Lysholm score,[32] Tegner activity level,[32] and the International Knee Documentation Committee (IKDC)[10] score were also used to assess outcome. The Lysholm score was self-administered according to the method of Höher et al.[11] Range of motion was measured to the nearest 5° by using a goniometer. Measurement of disturbances in sensitivity in the anterior knee region was performed by palpation and was measured in square centimeters. The patients were classified as having subjective anterior knee pain if they registered pain during stair-walking, sitting with the

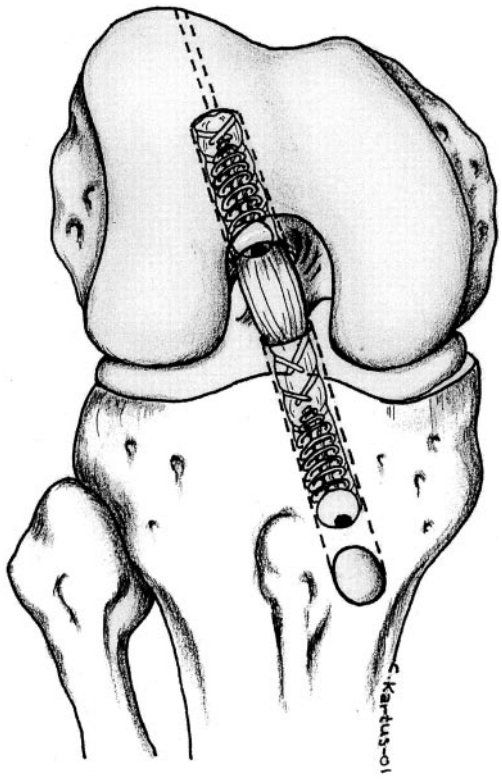

Figure 2. In the ST group, a 7-mm, round-headed, soft-threaded interference screw was used on both the femoral and tibial sides.

knee in 90° of flexion, and during or after activity. The classification of kneeling discomfort was performed by using the knee-walking test.[20] The single-legged hop test[33] and the isokinetic concentric peak torque test at 60 deg/sec as measured by a Cybex dynamometer (Hoover Inc., Austin, Texas) were used to evaluate functional performance.

Rehabilitation

All of the patients were rehabilitated according to the same protocol, which permitted immediate full weightbearing and full range of motion.[28] No rehabilitation brace was used in the study.[4,13,19] Closed kinetic chain exercises were started immediately after the operation. Terminal extension with an external load was not permitted during the first 6 postoperative weeks. Running was permitted at 3 months and contact sports at 6 months at the earliest, provided that the patient had regained full functional stability.

Statistical Methods

Median (range) values are presented, except for the absolute anterior KT-1000 arthrometer laxity measurements, for which mean (range) values are presented. Wilcoxon's signed rank test was used for comparisons of the preoperative and postoperative data within the groups. The Mann-Whitney *U*-test was used to compare the variables between the groups. The chi-square test was used to compare categorical variables. A P value of less than 0.05 was considered statistically significant.

RESULTS

Seventy-one patients were included in the study. In 34 patients, the central third of the patellar tendon was used as a graft (BTB group), and in 37 patients the semitendinosus tendon was used in the form of a tripled ($N = 14$) or quadrupled ($N = 23$) graft (ST group). The groups were comparable in terms of age, sex, preinjury Tegner activity level, and time between the injury and the initial operation (Table 1). One patient in the BTB group and two in the ST group suffered traumatic graft rupture during the follow-up period. One patient in each group was lost to follow-up because we were not able to locate them. Meniscal injuries identified and treated before the operation, during the operation, or during the follow-up period were documented in 23 of 32 patients in the BTB group and in 24 of 34 in the ST group (no significant difference). Articular surface damage or localized degenerative changes were found during the procedure in four patients in each group. One patient in each group had early swelling and a suspicious bacterial arthritis, but the cultures in the BTB patient were negative and the ST patient's were positive. Both patients healed after treatment with arthroscopic lavage and antibiotics.

At follow-up, there were no differences in terms of the Lysholm score, Tegner activity level score, and the single-legged hop test result between the study groups. However, both groups improved significantly between the preoperative assessment and the follow-up examination (Table 2).

The KT-1000 arthrometer anterior side-to-side difference at 89 N decreased significantly from before the operation to follow-up in the BTB group ($P = 0.03$), but in the ST group, the decrease did not reach statistical significance ($P = 0.08$). In terms of absolute values, the anterior laxity decreased significantly in both groups between the preoperative measurements and the measurements at follow-up. The manual Lachman test revealed significantly reduced laxity in the knees of both groups (Table 3). There was no difference between the study groups in terms of the IKDC evaluation score preoperatively and at the final follow-up (Table 4).

The disturbance in anterior knee sensitivity was a median of 0 cm^2 (range, 0 to 208) (three missing) in the BTB

TABLE 1
Preoperative Data of Patients in Both Groups

Variable	BTB group	ST group	Significance[a]
Number of patients	32	34	
Age (years)[b]	26 (14–49)	29 (15–59)	$P = 0.78$
Sex (female/male)	11/21	9/25	$P = 0.49$
Preinjury Tegner activity level[b]	9 (3–9)	9 (5–10)	$P = 0.76$
Time between the injury and operation (months)[b]	11 (2–252)	17.5 (3–360)	$P = 0.35$

[a] No difference was statistically significant.
[b] Median and range.

TABLE 2
The Lysholm Score, Tegner Activity Level Score, and Single-Legged Hop Test Score Preoperatively and at Follow-Up in Both Groups

Test	BTB group	ST group	Significance
	Median (range)	Median (range)	
Lysholm score			
Preoperatively	70 (14–95)	68 (21–100)	NS[a]
At follow-up	95 (46–100)	90 (51–100)	NS
Significance pre- vs. postoperative	$P < 0.001$	$P < 0.001$	
Tegner activity level score			
Preoperatively	3 (1–9)	4 (2–9)	NS
At follow-up	6 (1–9)	6.5 (3–9)	NS
Significance pre- vs. postoperative	$P < 0.001$	$P < 0.001$	
Single-legged hop test (%)			
Preoperatively	84 (0–111)	79 (0–108)	NS
At follow-up	92 (0–123) (one missing)	93 (0–122)	NS
Significance pre- vs. postoperative	$P = 0.005$	$P = 0.001$	

[a] Not significant.

group and 78 cm^2 (range, 0 to 342) (two missing) in the ST group ($P = 0.002$). No differences were found between the groups in terms of range of motion or the loss of extension or flexion. The range of motion was –5° (–15° to 5°) to 145° (135° to 155°) in the BTB group and –5° (–20° to 0°) to 150° (140° to 155°) in the ST group. Loss of extension or hyperextension of 5° or more compared with the healthy contralateral side was registered in 13 of 32 patients in the BTB group and in 9 of 34 patients in the ST group (no significant difference). The corresponding values for a flexion deficit of 5° of more were 16 of 32 in the BTB group and 24 of 34 in the ST group (no significant difference).

Strength was measured in 21 of 32 patients in the BTB group and in 31 of 34 in the ST group by using the Cybex dynamometer. On the injured side, there was a significant improvement in strength in terms of both extension and flexion, regardless of the type of graft used. At follow-up, there were no significant differences in strength in terms of both flexion and extension between the injured and noninjured side in either group (Table 5).

In the BTB group, 9 of 32 patients reported subjective anterior knee pain before the reconstruction. At follow-up, subjective anterior knee pain was reported by 6 of 32 patients. The corresponding values for the ST group were 12 of 33 (one missing) before the reconstruction and 7 of 33 (one missing) at follow-up. In terms of anterior knee pain, there was no significant difference between the groups either before the operation or at follow-up.

There was a significant difference between the groups in terms of the patients' ability to walk on their knees. At follow-up, 53% of patients in the BTB group (17 of 32) and 23% in the ST group (8 of 34) classified the knee-walking test as difficult or impossible to perform ($P = 0.01$). In the BTB group, knee-walking ability was significantly worse postoperatively compared with preoperatively ($P = 0.02$); this decline was not found among ST group patients ($P = 0.73$) (Table 6).

DISCUSSION

In a prospective randomized study, we compared use of the well-established and most frequently used central-third bone-patellar tendon-bone graft with use of a tripled or quadrupled semitendinosus tendon graft. Both grafts rendered similar improvements in function and laxity. The only clinically significant difference between the two

TABLE 3
Laxity Assessment Results of the KT-1000 Arthrometer and Manual Lachman Tests Preoperatively and at Follow-Up in Both Groups

Test	BTB group	ST group	Significance
KT-1000 anterior side-to-side difference at 89 N			
Preoperatively	3.75 mm (−3–17) (two missing)	3.75 mm (−2–24)	NS[a]
At follow-up	2.0 mm (−5–11.5)	2.25 mm (−4–10.5)	NS
Significance pre- vs. postoperative	$P = 0.03$	NS ($P = 0.08$)	
Absolute KT-1000 anterior translation at 89 N injured side (mean)			
Preoperatively	11.6 mm (4–29) (two missing)	12.1 mm (5–30)	NS
At follow-up	9.0 mm (4–16.5)	9.5 mm (2.5–17)	NS
Significance pre- vs. postoperative	$P = 0.02$	$P = 0.01$	

Manual Lachman test	BTB group				ST group				
	(0)	(+)	(++)	(+++)	(0)	(+)	(++)	(+++)	
Preoperatively	0	2	10	20	0	7	17	10	$P = 0.01$
At follow-up	18	12	2	0	16	17	0	0	NS
Significance pre- vs. postoperative	$P < 0.0001$				$P < 0.0001$				

[a] Not significant.

TABLE 4
The IKDC Evaluation Preoperatively and at Final Follow-Up in Both Groups

IKDC rating	BTB group		ST group		Significance
	N	(%)	*N*	(%)	
Preoperatively					
Normal or nearly normal	0		0		NS[a]
Abnormal or severely abnormal	32/32	(100)	34/34	(100)	NS
At follow-up					
Normal or nearly normal	17/32	(53)	20/34	(59)	NS
Abnormal or severely abnormal	15/32	(47)	14/34	(41)	NS

[a] Not significant.

TABLE 5
Muscle Strength Measured as Peak Torque at 60 deg/sec (pounds/square inch) in Both Extension and Flexion, Preoperatively and at Follow-Up on the Injured and Uninjured Side

Measurement	BTB group ($N = 21$)	ST group ($N = 31$)
	Median (range)	Median (range)
Extension (injured side)		
Preoperatively	135 (35–410)	190 (0–490); mean 185
At follow-up	180 (60–360)	190 (50–465); mean 203
Significance pre- vs. postoperative	$P = 0.05$	$P = 0.03$
Extension (uninjured side)		
Preoperatively	185 (40–350)	225 (65–410)
At follow-up	210 (60–540)	215 (70–450)
Significance pre- vs. postoperative	$P = 0.04$	NS[a] ($P = 0.19$)
Significance at follow-up for injured side vs. uninjured side	NS ($P = 0.16$)	NS ($P = 0.24$)
Flexion (injured side)		
Preoperatively	90 (0–250)	130 (0–350)
At follow-up	120 (0–300)	180 (0–470)
Significance pre- vs. postoperative	$P = 0.01$	$P = 0.02$
Flexion (uninjured side)		
Preoperatively	150 (0–320)	160 (0–375)
At follow-up	100 (20–320)	190 (0–420)
Significance pre- vs. postoperative	NS ($P = 0.11$)	$P < 0.01$
Significance at follow-up for injured side vs. uninjured side	NS ($P = 0.06$)	NS ($P = 0.14$)

[a] Not significant.

TABLE 6
Knee-Walking Ability Preoperatively and at Follow-Up in Both Groups

Knee-walking test	BTB group		ST group		Significance
	N	(%)	*N*	(%)	
Preoperatively					
Normal	12/32	(37.5)	16/34	(47)	
Unpleasant	14/32	(44)	14/34	(41)	
Difficult	4/32	(12.5)	3/34	(9)	
Impossible	2/32	(6)	1/34	(3)	NS[a] ($P = 0.40$)
At follow-up					
Normal	6/32	(19)	21/34	(62)	
Unpleasant	9/32	(28)	5/34	(15)	
Difficult	5/32	(15.5)	6/34	(17)	
Impossible	12/32	(37.5)	2/34	(6)	$P = 0.01$
Significance pre- vs. postoperative	$P = 0.02$		NS ($P = 0.73$)		

[a] Not significant.

methods was that the ST group patients had a better ability to walk on their knees.

The strength of this study was its prospective and randomized design, the fact that one surgeon performed all of the reconstructions, and that unbiased observers, not involved in the operation or rehabilitation, performed the pre- and postoperative evaluations. Except for the use of a soft-threaded type of interference screw in the ST group patients, the only variable that differed between the study groups was the type of graft. All other important factors for the final outcome, such as fixation technique and the rehabilitation protocol, were identical.

In previous studies, donor site problems have been described after ACL reconstruction with bone-patellar tendon-bone autografts. Loss of full range of motion and disturbances in knee sensitivity have been proposed as factors correlating with subjective anterior knee pain and discomfort during kneeling and walking on one's knees.[14,18,29] It is our opinion that knee-walking and kneeling ability have major clinical significance in the age group undergoing ACL reconstruction. The patients are often employed in construction or cleaning work that requires kneeling or may be playing with children on the floor. Furthermore, most major religions have ceremonies in which kneeling is important.

In previous studies, we have suggested that injury to the infrapatellar nerve branches could influence a patient's ability to walk on his or her knees.[17,20] With use of the central-third bone-patellar tendon-bone graft harvested by using the one-incision technique, we noticed that afterward 65% of the patients (36 of 55) found it difficult or impossible to walk on their knees.[17] Change of the harvesting technique from traditional to subcutaneous resulted in significantly less disturbance in knee sensitivity and a tendency toward fewer problems during knee-walking. In this study, 53% of the patients in the BTB group and 23% in the ST group found it difficult or impossible to walk on their knees. It must be remembered that 16% of the patients in the present study found it difficult or impossible to perform this test preoperatively. Therefore, we believe that use of the semitendinosus tendon graft for ACL reconstruction reduces postoperative knee-walking problems.

In this study, there was a significant difference in terms of the disturbance in anterior knee sensitivity between the groups, favoring the BTB group, when the graft was harvested subcutaneously. When injury is caused to the infrapatellar nerve branches during bone-patellar tendon-bone graft harvest, the possible subsequent neuromas are in direct contact with the floor when the patient walks on his or her knees. This is in contrast to what happens when the nerve is injured during harvest of semitendinosus tendon grafts. The possible neuromas are then outside the area loaded during walking on one's knees. Another cause of the difficulty BTB group patients had in walking on their knees could be that the harvesting technique created a bone defect in the tibial tubercle, which also has to withstand direct pressure during knee-walking. Tenderness over the tibial tubercle has also previously been suggested as a cause of kneeling difficulties.[34] However, Brandsson et al.[3] did not find fewer anterior knee problems or donor site problems when the defects in the patella and tibial tubercle were filled by bone grafting. Boszotta and Prünner[2] also found that bone grafting did not reduce kneeling problems or patellofemoral pain.

We were not able to demonstrate any significant differences in subjective anterior knee pain between the study groups at follow-up. Nor was there any increase in anterior knee pain between the preoperative evaluation and the follow-up examination. Furthermore, there were no significant differences between the groups in terms of loss of extension or flexion, which have both been previously suggested as frequent causes of anterior knee pain.[18,31] It is notable that subjective anterior knee pain was already present before the reconstruction in several patients and that 2 years later there was, instead, a tendency toward less subjective anterior knee pain.

In this study, we used the same fixation technique for both types of graft. Use of the interference screw has been questioned for the fixation of tendon grafts, especially on the tibial side.[30] Clinically, this does not appear to be a problem. The fixation techniques that are used today probably only need to withstand the stress on the graft complex during the first 10 to 12 weeks. The forces that theoretically act on the graft complex, when permitting full weightbearing and closed kinetic chain exercises without loaded terminal extension, are estimated to be less than 400 N and thus under the pull-out limits for many fixation techniques.[22,24] We did not find any negative effects on function or stability in the ST group patients from the fixation technique and rehabilitation protocol that were used. A possible advantage of the interference screw technique is the short distance between the fixation points, which results in less stress and strain that could cause graft elongation and tunnel widening.[12]

The overall results of the present study, as measured by the IKDC evaluation system, were 53% normal or nearly normal in the BTB group and 59% normal or nearly normal in the ST group. This result is in line with those of Eriksson et al.[8] in their randomized study with unbiased observers. However, these results are worse than those from studies with other designs that presented nearly normal or normal results of up to 80% to 90%.[6,13,14,25] The ACL reconstruction does not result in a normal knee, but it gives the patient the chance to return to sporting activities, although usually at a lower level than before the injury. In the present study, the activity level was reduced by two to three units on the Tegner scale in both groups compared with their preinjury level.

Harvest of a tendon from the hamstring muscles could theoretically reduce flexion strength, and use of a semitendinosus tendon graft could therefore be less favorable than that of bone-patellar tendon-bone graft in this respect. Because we had too few strength measurements from BTB group patients, we were not able to compare the groups. In the ST group, however, we found a significant improvement in flexion strength at follow-up compared with the preoperative values and, furthermore, no significant difference between the injured and noninjured sides. As a result, we believe that the proposed risk of reduced flexion strength from use of semitendinosus tendon grafts for ACL reconstruction is exaggerated, at least in the perspective of 2 years after reconstruction. One explanation for this result could be the reported regeneration potential for the semitendinosus tendon in three-quarters of patients.[9]

On the basis of the results of the present study and other controlled studies, we conclude that the semitendinosus tendon graft is a useful one and is at least an equivalent option to the bone-patellar tendon-bone graft for ACL reconstruction.[1,8,23,25] We were not able to identify any disadvantages from use of the semitendinosus tendon graft at the follow-up examination 2 years after

reconstruction. If controlled long-term studies do not reveal an unexpected increase of laxity or impaired function after reconstruction with the semitendinosus tendon graft, it might become the first choice for ACL reconstruction. The most striking difference of clinical relevance was that the patients in the ST group had significantly better ability to walk on their knees. We were able to verify our hypothesis, and we therefore recommend use of the semitendinosus tendon graft for ACL reconstruction.

ACKNOWLEDGMENTS

This study was supported by grants from the Research and Development Department of Northern Älvsborg/Bohuslandstinget and the Swedish National Centre for Research in Sports. The authors thank Catarina Kartus for the illustrations.

REFERENCES

1. Aglietti P, Buzzi R, Zaccherotti G, et al: Patellar tendon versus doubled semitendinosus and gracilis tendons for anterior cruciate ligament reconstruction. *Am J Sports Med 22:* 211–218, 1994
2. Boszotta H, Prünner K: Refilling of removal defects: Impact on extensor mechanism complaints after use of a bone-tendon-bone graft for anterior cruciate ligament reconstruction. *Arthroscopy 16:* 160–164, 2000
3. Brandsson S, Faxén E, Eriksson BI, et al: Closing patellar tendon defects after anterior cruciate ligament reconstruction: Absence of any benefit. *Knee Surg Sports Traumatol Arthrosc 6:* 82–87, 1998
4. Brandsson S, Faxén E, Kartus J, et al: Is a knee brace advantageous after anterior cruciate ligament surgery? A prospective, randomised study with a two-year follow-up. *Scand J Med Sci Sports 11:* 110–114, 2001
5. Buss DD, Warren RF, Wickiewicz TL, et al: Arthroscopically assisted reconstruction of the anterior cruciate ligament with use of autogenous patellar-ligament grafts. Results after twenty-four to forty-two months. *J Bone Joint Surg 75A:* 1346–1355, 1993
6. Corry IS, Webb JM, Clingeleffer AJ, et al: 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, 1999
7. Daniel DM, Malcom LL, Losse G, et al: Instrumented measurement of anterior laxity of the knee. *J Bone Joint Surg 67A:* 720–726, 1985
8. Eriksson K, Anderberg P, Hamberg P, et al: A comparison of quadruple semitendinosus and patellar tendon grafts in reconstruction of the anterior cruciate ligament. *J Bone Joint Surg 83B:* 348–354, 2001
9. Eriksson K, Larsson H, Wredmark T, et al: Semitendinosus tendon regeneration after harvesting for ACL reconstruction. A prospective MRI study. *Knee Surg Sports Traumatol Arthrosc 7:* 220–225, 1999
10. Hefti F, Müller W, Jakob RP, et al: Evaluation of knee ligament injuries with the IKDC form. *Knee Surg Sports Traumatol Arthrosc 1:* 226–234, 1993
11. Höher J, Bach T, Münster A, et al: Does the mode of data collection change results in a subjective knee score? Self-administration versus interview. *Am J Sports Med 25:* 642–647, 1997
12. Höher J, Möller HD, Fu FH: Bone tunnel enlargement after anterior cruciate ligament reconstruction: Fact or fiction? *Knee Surg Sports Traumatol Arthrosc 6:* 231–240, 1998
13. Howell SM, Taylor MA: Brace-free rehabilitation, with early return to activity, for knees reconstructed with a double-looped semitendinosus and gracilis graft. *J Bone Joint Surg 78A:* 814–825, 1996
14. Järvelä T, Kannus P, Järvinen M: Anterior knee pain 7 years after an anterior cruciate ligament reconstruction with a bone-patellar tendon-bone autograft. *Scand J Med Sci Sports 10:* 221–227, 2000
15. Järvinen M, Natri A, Lehto M, et al: Reconstruction of chronic anterior cruciate ligament insufficiency in athletes using a bone-patellar tendon-bone autograft. A two-year follow up study. *Int Orthop 19:* 1–6, 1995
16. Kartus J, Ejerhed L, Eriksson BI, et al: The localization of the infrapatellar nerves in the anterior knee region with special emphasis on central third patellar tendon harvest: A dissection study on cadaver and amputated specimens. *Arthroscopy 15:* 577–586, 1999
17. Kartus J, Ejerhed L, Sernert N, et al: Comparison of traditional and subcutaneous patellar tendon harvest. A prospective study of donor site-related problems after anterior cruciate ligament reconstruction using different graft harvesting techniques. *Am J Sports Med 28:* 328–335, 2000
18. Kartus J, Magnusson L, Stener S, et al: Complications following arthroscopic anterior cruciate ligament reconstruction. A 2–5-year follow-up of 604 patients with special emphasis on anterior knee pain. *Knee Surg Sports Traumatol Arthrosc 7:* 2–8, 1999
19. Kartus J, Stener S, Köhler K, et al: Is bracing after anterior cruciate ligament reconstruction necessary? A 2-year follow-up of 78 consecutive patients rehabilitated with or without a brace. *Knee Surg Sports Traumatol Arthrosc 5:* 157–161, 1997
20. Kartus J, Stener S, Lindahl S, et al: Factors affecting donor site morbidity after anterior cruciate ligament reconstruction using bone-patellar tendon-bone autografts. *Knee Surg Sports Traumatol Arthrosc 5:* 222–228, 1997
21. Kurosaka M, Yoshiya S, Andrish JT: A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction. *Am J Sports Med 15:* 225–229, 1987
22. Magen HE, Howell SM, Hull ML: Structural properties of six tibial fixation methods for anterior cruciate ligament soft tissue grafts. *Am J Sports Med 27:* 35–43, 1999
23. Marder RA, Raskind JR, Carroll M: Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction. Patellar tendon versus semitendinosus and gracilis tendons. *Am J Sports Med 19:* 478–484, 1991
24. Noyes FR, Butler DL, Grood ES, et al: Biomechanical analysis of human ligament grafts used in knee-ligament repairs and reconstructions. *J Bone Joint Surg 66A:* 344–352, 1984
25. O'Neill DB: Arthroscopically assisted reconstruction of the anterior cruciate ligament. A prospective randomized analysis of three techniques. *J Bone Joint Surg 78A:* 803–813, 1996
26. Roos H, Karlsson J: Anterior cruciate ligament instability and reconstruction. Review of current trends in treatment. *Scand J Med Sci Sports 8:* 426–431, 1998
27. Rosenberg TD: *Endoscopic Technique for ACL Reconstruction with Pro-Trac Tibial Guide.* Acufex Microsurgical Inc, Mansfield, MA, 1991
28. Shelbourne KD, Nitz P: Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am J Sports Med 18:* 292–299, 1990
29. Shelbourne KD, Trumper RV: Preventing anterior knee pain after anterior cruciate ligament reconstruction. *Am J Sports Med 25:* 41–47, 1997
30. Shino K, Pflaster DS: Comparison of eccentric and concentric screw placement for hamstring graft fixation in the tibial tunnel. *Knee Surg Sports Traumatol Arthrosc 8:* 73–75, 2000
31. Stapleton TR: Complications in anterior cruciate ligament reconstructions with patellar tendon grafts. *Sports Med Arthrosc Rev 5:* 156–162, 1997
32. Tegner Y, Lysholm J: Rating systems in the evaluation of knee ligament injuries. *Clin Orthop 198:* 43–49, 1985
33. Tegner Y, Lysholm J, Lysholm M, et al: A performance test to monitor rehabilitation and evaluate anterior cruciate ligament injuries. *Am J Sports Med 14:* 156–159, 1986
34. Victor J, Bellemans J, Witvrouw E, et al: Graft selection in anterior cruciate ligament reconstruction—prospective analysis of patellar tendon autografts compared with allografts. *Int Orthop 21:* 93–97, 1997