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# A Prospective, Randomized Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction

## Five-Year Follow-Up

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**Background:** There are still controversies about graft selection for primary anterior cruciate ligament reconstruction. Prospective randomized long-term studies are needed to determine the differences between the materials.

**Hypothesis:** Five years after anterior cruciate ligament reconstruction, there is a difference between hamstring and patellar tendon grafts in development of degenerative knee joint disease.

**Study Design:** Randomized controlled trial; Level of evidence, 1.

**Methods:** From June 1999 to March 2000, 64 patients were included in this prospective study. A single surgeon performed primary arthroscopically assisted anterior cruciate ligament reconstruction in an alternating sequence. In 32 patients, anterior cruciate ligament reconstruction was performed with hamstring tendon autograft, whereas in the other 32 patients, anterior cruciate ligament reconstruction was performed with patellar tendon autograft.

**Results:** At the 5-year follow-up, no statistically significant differences were seen with respect to the Lysholm score, clinical and KT-2000 arthrometer laxity testing, anterior knee pain, single-legged hop test, or International Knee Documentation Committee classification results; 23 patients (82%) in the hamstring tendon group and 23 patients (88%) in the patellar tendon group returned to their preinjury activity levels. Graft rupture occurred in 2 patients from the hamstring tendon group (7%) and in 2 patients from the patellar tendon group (8%). Grade B abnormal radiographic findings were seen in 50% (13/26) of patients in the patellar tendon group and in 17% (5/28) of patients in the hamstring tendon group ( $P = .012$ ).

**Conclusion:** Both hamstring and patellar tendon grafts provided good subjective outcomes and objective stability at 5 years. No significant differences in the rate of graft failure were identified. Patients with patellar tendon grafts had a greater prevalence of osteoarthritis at 5 years after surgery.

**Keywords:** anterior cruciate ligament (ACL) reconstruction; hamstring tendons; semitendinosus and gracilis tendon; patellar tendon; cannulated interference screws; long-term clinical study

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Anterior cruciate ligament rupture is the most common serious injury of the knee.<sup>12</sup> Increased participation of all ages in sports has resulted in an increase in the incidence of ACL

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tears. Functional instability, especially in the active sporting population, has been found to be associated with meniscal and chondral injuries as well as with the development of degenerative joint disease.<sup>13,16,23,25,33,34</sup> However, an increased incidence of osteoarthritic change has been found after surgical reconstruction as well.<sup>18</sup> Successful treatment of the ACL-insufficient knee, whether nonoperative or operative, has to preserve intact meniscal and chondral structures.<sup>1,32</sup> This supports the concept of early ACL reconstruction in the active population, before the onset of joint degradation. The goals of ACL reconstruction are to provide a functionally

stable knee, decrease symptoms, and return patients to their preinjury activity levels. While obtaining these goals, however, the surgeon also wishes to minimize the complications of graft harvest to the patient. The most commonly used grafts for ACL reconstruction are patellar tendon and semitendinosus and gracilis (hamstring) tendon autografts. The disadvantages of patellar tendon autografts are the risk of patellar fracture, potential increase in patellofemoral pain and kneeling pain, and retained patellar tendon weakness or rupture.<sup>5,21,22,28</sup> Disadvantages of hamstring tendon autografts include potential hamstring muscle weakness<sup>6</sup> and slower healing of the graft attachment site.<sup>39</sup> Bone-to-bone healing is similar to fracture healing and is stronger and faster than is soft tissue healing. Graft fixation is crucial in ACL reconstruction and is the weakest link in the initial 6- to 12-week period, during which healing of the graft to the host bone occurs.<sup>39</sup> Suspensory methods (ie, fixation outside the tunnel) and aperture methods (by interference screw close to the origin and insertion) of fixation have been described, with aperture fixation resulting in increased stiffness of the construction compared with the suspensory method.<sup>15,19,24,35,36</sup> The strength examinations of the reconstructed ACL with double-looped hamstring tendon and patellar tendon show similar biomechanical properties when comparing both autografts.<sup>29</sup>

Despite an abundance of literature on ACL reconstruction and its outcome, there are little data directly comparing hamstring tendon autograft and patellar tendon autograft to aid the patient and surgeon in selecting the appropriate graft. In an evidence-based medicine hierarchy, a surgeon should ideally base decisions on randomized controlled trials or controlled prospective comparative studies.<sup>35</sup> In 1996, O'Neill<sup>26</sup> published one of the early controlled prospective comparative studies evaluating differences between the patellar tendon autograft and hamstring tendon autograft. Since 2000, 7 additional randomized controlled trials have been published.<sup>2-4,8,10,17,31</sup> The present study is a prospectively randomized 5-year follow-up study designed to compare the outcome after arthroscopic single-incision ACL reconstruction with 4-strand hamstring tendon or patellar tendon autografts, both fixed with interference screws by the same surgeon using the same surgical technique, and aggressive postoperative rehabilitation. The hypotheses were that (1) the use of the hamstring tendon autografts in ACL reconstruction provides good knee stability to the same extent as do bone-patellar tendon-bone autografts and (2) patients with patellar tendon autografts in ACL reconstruction are at greater risk of developing early signs of osteoarthritis.

## MATERIALS AND METHODS

### Patient Selection

In this study, the key indication for surgical reconstruction was a clinical diagnosis of ACL rupture in a patient desiring to return to his or her preinjury level of activity. Patients with associated ligament injury, previous meniscectomy, an abnormality seen radiographically, or an abnormal contralateral knee joint, as well as those who did not wish to

participate in a research program, were excluded from the study. Also, patients who required revision surgery during the follow-up period were excluded from the analysis. From April 1999, the patients who fulfilled the study inclusion criteria were automatically entered into a hospital database for ACL reconstruction. From June 1999 to March 2000, 64 patients were operated on from this list. Patients underwent a primary arthroscopically assisted ACL reconstruction and graft randomization into a patellar or hamstring tendon group according to operative registration list position (even number, patellar tendon; odd number, hamstring tendon). In 32 patients, ACL reconstruction was performed with doubled semitendinosus and gracilis tendon autograft, whereas in the other 32 patients, ACL reconstruction was performed with patellar tendon autograft. All patients signed an informed consent form. The study was approved by the national ethical committee.

### Operative Technique

All procedures were performed by the first author (M. S.). Apart from the graft, the surgical technique was identical. All patients were examined under anesthesia (Lachman, drawer, pivot-shift, and rotation tests), after which routine diagnostic arthroscopy and meniscal surgery were performed, followed by the ACL reconstruction. The femoral tunnel was drilled through the anteromedial portal before the tibial tunnel was drilled.

In the hamstring tendon group, the surgical procedure was an arthroscopic single-incision technique with double-looped semitendinosus and gracilis tendons. The drill tunnels were 8 or 9 mm in diameter. Drill guides were used to confirm the correct position of the tunnels. To find the femoral entry point, we used the "bull's eye" drill guide (Linvatec Inc, Largo, Fla). Tunnel size was matched to the cross-sectional size of the graft. A marking suture using No. 0 absorbable suture was set 2.5 cm from the femoral end of the graft to ensure good entry of the graft in the tunnel and to prevent the graft from twisting around the screw during insertion. The graft was inserted retrograde via the tibial tunnel into a blind femoral tunnel. The first author (M. S.) designed left-thread and right-thread, round-head cannulated interference (RCI) screws (ART-MAM, Slovenia) for femoral graft fixation. In right knees, the screw with a left thread was used, and in left knees the screw with a right thread was used. This prevented graft impingement against the lateral wall of the intercondylar notch. Tibial anatomical joint line fixation was achieved using a bioabsorbable interference screw (Linvatec) in an outside-in direction at a knee flexion angle of approximately 10° and manual pretension.

In the patellar tendon group, the surgical procedure was an arthroscopic single-incision technique with the central third of the ipsilateral bone-patellar bone-tendon used as a free autograft with matching drill tunnels made in the femur and tibia. The defects of the patella and the proximal tibia were not bone grafted. Tunnel size in the patellar tendon group was determined as 1 mm larger than the bone block size. The fixation of the graft in the drill tunnels was performed proximally with the metal RCI screw and distally with the bioabsorbable interference screw.

## Rehabilitation

All the patients were rehabilitated according to the same accelerated protocol, which permitted immediate full weight-bearing and full range of motion.<sup>33</sup> A rehabilitation brace was used for 3 weeks postoperatively. The splint was not worn during the rehabilitation protocol and during the night. The importance of reaching full extension was emphasized from the beginning. The patients had to obtain an arc of at least 0° to 90° before they were discharged from the hospital. Closed kinetic chain exercises were started immediately after the operation. The leg extension exercise against resistance in the arc of 45° to 0° was not allowed during the first 6 postoperative weeks. Running was allowed at 8 weeks and contact sports at 6 months under 3 conditions: (1) no effusion, (2) full range of motion, and (3) obtained muscle strength of 90% compared with the contralateral side.

## Follow-up Evaluation

Clinical evaluations of knee function and stability were assessed preoperatively, at 2 weeks, at 6 weeks, and at 3 and 5 months after surgery by the first author (M. S.). At 5-year follow-up, clinical and radiographic evaluations were performed by 2 senior authors (V. V. and R. K.). The physical therapist (K. S.), who was not involved in postoperative rehabilitation, performed all arthrometric assessments.

The Lysholm knee score questionnaire<sup>37</sup> was sent to the patients by mail and completed in their home environments. The International Knee Documentation Committee (IKDC) activity level<sup>14</sup> was used to assess the functional outcome. Patients were evaluated using the IKDC score according to the 2000 IKDC Knee Examination Form. The additional subjective outcome was assessed with the questions, "How does your knee function?" and "How does your knee influence your activity?" Range of motion was measured to the nearest 5° by using a goniometer and bony landmarks at the lateral malleolus of the ankle, knee joint line, and greater trochanter of the hip. Clinical ligament testing was performed by means of the Lachman test, anterior drawer test, and pivot-shift test, with side-to-side differences recorded. Objective anteroposterior knee stability was determined by using the KT-2000 arthrometer (MEDmetric, San Diego, Calif) at 89 and 134 N manual tension and a knee flexion angle of 25°. We selected 3 mm as the upper limit of normality of side-to-side difference in anterior tibial displacement. The manual maximum displacement test was not relevant because the physical therapist was not able to produce a greater force than 134 N and fix the patella at the same time. After the evaluation of the IKDC score, we graded these parameters as A (normal), B (nearly normal), C (abnormal), or D (severely abnormal) compared with the patients' preoperative conditions or the control knees.

The patients were classified as having subjective anterior knee pain if they registered pain during or after activity, during stair walking, or during squatting or kneeling. Before surgery and at 5 years after surgery, weightbearing anteroposterior and lateral radiographs at 30° of flexion were obtained. Patients with abnormal radiographs before surgery have not been included in the study. Radiographic evaluation

was done according to IKDC recommendations (A, normal; B, minimal changes and barely detectable joint space narrowing; C, minimal changes and joint space narrowing up to 50%; D, more than 50% joint space narrowing). The single-legged hop test was used to evaluate functional performance.

## Statistical Methods

On April 23, 1999, a hospital database with all preoperative and postoperative variables was established. Statistical analysis was performed by an independent expert not involved in the study protocol (R. T.). Median (range) values are presented, except for the absolute anterior KT-2000 arthrometer laxity measurements, for which mean (range) values are presented. The paired *t* test was used for comparisons of the preoperative and postoperative numerical data (KT-2000 arthrometer, range of motion, Lysholm score) and the unpaired *t* test for numerical data within the groups. The  $\chi^2$  test was used to compare categorical variables (overall IKDC scores, the severity of osteoarthritis). A *P* value less than .05 was considered statistically significant.

## RESULTS

Of the 64 total patients in the study, 54 (85%) were available for the 5-year follow-up. Of the 10 patients not available, 1 patient in the hamstring tendon group and 2 patients in the patellar tendon group were lost to follow-up. The remaining 7 patients were excluded owing to a contralateral ACL rupture or revision ACL surgery of the knee. During the study period, 3 patients in the patellar tendon group and 2 patients in the hamstring tendon group had treatment for a contralateral ACL rupture. Furthermore, 1 female patient in the hamstring tendon group had a skiing reinjury of the reconstructed knee, and 1 male patient in the patellar tendon group had a beach volleyball reinjury, so revision ACL reconstruction in both patients had been performed. A total of 54 patients, 28 patients in the hamstring tendon group and 26 patients in the patellar tendon group, were clinically examined and radiographically evaluated at 5-year follow-up.

The comparison between the hamstring tendon and the patellar tendon groups in relation to preoperative and intraoperative parameters showed that the 2 groups were comparable. None of the patients' radiographs showed evidence of knee joint osteoarthritis. There were no significant differences between the 2 groups regarding age, sex, preinjury activity level, preoperative Lysholm knee scores, or interval from injury to surgery (Table 1). The ACL was reconstructed at less than 12 weeks after injury in 4 of 28 patients (14%) in the hamstring tendon group and in 4 of 26 patients (15%) in the patellar tendon group.

Medial meniscal injury was noted at the time of reconstruction in 12 of 28 hamstring tendon patients (43%) and in 12 of 26 patellar tendon patients (46%). Lateral meniscal injury was observed in 6 of 28 hamstring tendon patients (21%) and in 6 of 26 patellar tendon patients (23%). The menisci were sutured in 2 patients from the hamstring tendon group (7%) and in 1 patient from the patellar tendon group (4%). The arthroscopic procedures were performed

TABLE 1  
Comparison of Randomized Groups

Variable	Hamstring Tendon Group	Patellar Tendon Group	<i>P</i>
Total no. of patients	28	26	
Mean age, y (range)	24 (14-42)	27 (16-46)	
Gender			
Male	13	14	
Female	15	12	
International Knee Documentation Committee preinjury activity level			
Level I	18	18	
Mean preoperative Lysholm scores (range)	57 (9-82)	55 (16-77)	.611
Mean time from injury to surgery, mo (range)	25 (1-84)	23 (1-60)	
Acute reconstruction (%)	4 (14)	4 (15)	
Chronic reconstruction (%)	24 (86)	22 (85)	
Meniscal surgery (%)	20 (71)	19 (73)	
Meniscal repair (%)	2 (7)	1 (4)	
Partial resection (%)	6 (21)	14 (54)	
Subtotal resection (%)	12 (43)	4 (15)	.027

with nonabsorbable sutures according to the inside-out technique. Unfortunately, there were significant differences between the 2 groups according to subtotal meniscal resection ( $P = .027$ ). Subtotal meniscal resections were performed in 12 of 28 hamstring tendon patients (43%) and in 4 of 26 patellar tendon patients (15%).

There were no infections, deep venous thromboses, nerve injuries, or other operative complications in this series. The median length of hospital stay was 3 nights (range, 2-4 nights) for the hamstring tendon group and 4 nights (range, 2-6 nights) for the patellar tendon group. All patients were comfortable with the postoperative rehabilitation protocol. Full extension was achieved during early postoperative rehabilitation. There were no signs of arthrofibrosis or impingement syndrome, so further surgeries were not required. One patient in the hamstring tendon group had a traumatic injury during a judo national championship. An arthroscopic procedure was performed and an intact ACL was found; however, partial resection of a torn medial meniscus had to be done. In the hamstring tendon group, 2 patients (7%) had graft ruptures, and 2 patients (6%) ruptured their contralateral ACLs. In the patellar tendon group, there were 2 cases (8%) of graft ruptures, and 3 patients (9%) ruptured their contralateral ACLs. There was no significant difference between the hamstring tendon and patellar tendon groups in the rate of ACL graft rupture or contralateral ACL rupture.

Preoperative versus postoperative Lysholm knee scores showed a significant improvement in both groups (hamstring tendon,  $P < .001$ ; patellar tendon,  $P < .001$ ). At 5-year follow-up, there were no statistically significant differences between the groups with respect to Lysholm knee scores (Table 2). In the hamstring tendon group, the mean Lysholm score was 92 (range, 74-100), and in the patellar

TABLE 2  
Lysholm Knee Scores 5 Years Postoperatively<sup>a</sup>

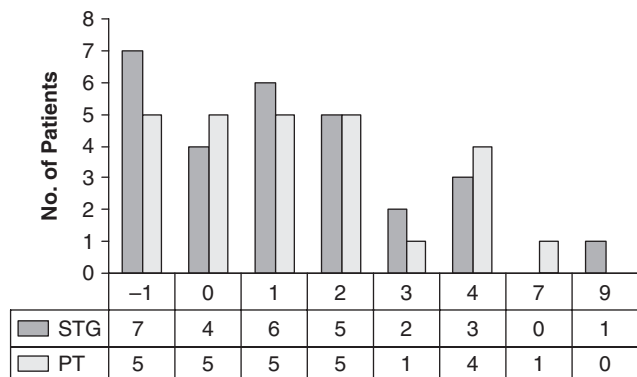
Lysholm Score	Hamstring Tendon Group (n = 28)		Patellar Tendon Group (n = 26)	
	n	%	n	%
Excellent (95-100)	16	58	11	43
Good (84-94)	9	32	13	50
Fair (65-83)	3	10	2	7
Poor (<65)	0	0	0	0

<sup>a</sup> $P = .888$ .

tendon group, the mean score was 92 (range, 62-100). Twenty-three patients (82%) in the hamstring tendon group and 23 patients (88%) in the patellar tendon group returned to their preinjury activity levels. The single-legged hop test of knee function determines the ratio of distance achieved by hopping on the involved limb compared with the contralateral normal limb. A grade A hop on the involved side is a distance equal to or greater than 90% of that achieved with the contralateral limb. At 5 years, 26 patients (93%) of the hamstring tendon group and 24 patients (92%) of the patellar tendon group had achieved a grade A hop.

We found that anterior knee pain and kneeling pain were only a minor problem. Patients reported anterior knee pain during strenuous activities or in the kneeling-squatting position in 17% in the hamstring tendon group and in 19% in the patellar tendon group. The range of motion of the reconstructed knee was physiological compared with the healthy contralateral limb in both groups, except in 3 patients (11%) from the patellar tendon group in whom a 10° lack of terminal passive flexion was measured. We did not find any loss of extension in either group.

On clinical examination at the 5-year follow-up, there was a positive pivot-shift test result in 1 patient in the hamstring tendon group and in 1 patient in the patellar tendon group (Table 3). We could not find any objective explanation why graft failures occurred. The time from injury to operation was 6 months in the patient from the hamstring tendon group and 5 months in the patient from the patellar tendon group. Postoperative anterior laxity values measured with the KT-2000 arthrometer, grouped as proposed by the IKDC (A, 0-2 mm; B, 3-5 mm; C, 6-10 mm; D, >10 mm), did not result in a significant difference. The mean value of anterior laxity measured with the KT-2000 arthrometer at 134 N of manual tension (side-to-side difference) was  $1.6 \pm 2.4$  mm for the hamstring tendon group and  $1.9 \pm 2.0$  mm for the patellar tendon group ( $P = .646$ ). In the hamstring tendon group, 78% (22/28) scored 3 mm or less difference, as did 76% (20/26) of the patellar tendon group. Three percent of the hamstring tendon group (1/28) and 3% of the patellar tendon group (1/26) scored more than 5 mm. Figure 1 represents all KT-2000 arthrometer side-to-side difference measurements performed at 5-year follow-up. Twelve knees (22%) had negative (-1 mm) KT-2000 arthrometer results.



**Figure 1.** Comparison of anterior laxity at 5 years after surgery measured with the KT-2000 arthrometer (side-to-side difference in millimeters, at 134-N manual tension). Mean value was 1.6 ± 2.4 mm for the hamstring tendon (STG) group and 1.9 ± 2.0 mm for the bone–patellar tendon–bone (PT) group (*P* = .646). STG, semitendinosus and gracilis tendon; PT, patellar tendon.

It is known that arthrofibrosis causes loss of motion, as well as rigid and painful knee joint. However, in arthrofibrotic knees, the KT-2000 arthrometer measurements express higher negative results. In our study, the patients with negative KT-2000 arthrometer results had no clinical signs of arthrofibrosis at any point during the rehabilitation protocol. Two knees had abnormal results (7 mm and 9 mm) that correlated with the clinical examination and the patients' subjective opinions. Exclusion of negative or abnormal KT-2000 arthrometer results from the analysis does not significantly affect the mean value of KT-2000 arthrometer measurements. Comparison of objective anteroposterior knee stability associated with the patient's gender indicated significant differences. We found that the mean 134-N side-to-side difference for men was 1.1 ± 2.4 mm and for women 2.4 ± 1.9 mm (*P* = .031).

As stated previously, the IKDC system was used for grading radiographs. The medial, lateral, and patellofemoral compartments were examined for evidence of joint space narrowing and for the presence of osteophytes. The worst compartment grading was used as the overall grade. Radiographic evidence of knee joint osteoarthritis grade B was present in 50% (13/26) of patients in the patellar tendon group and in 17% (5/28) of patients in the hamstring tendon group, which was statistically significant (*P* = .012). Table 4 represents the IKDC documentation grading of degenerative joint disease comparing hamstring and patellar tendon groups. Four patients (15%) in the patellar tendon group expressed grade B patellofemoral osteoarthritis, which represents some clinical and functional problems. Three patients had a 10° lack of terminal passive flexion with difficulties while kneeling or squatting and subsequent anterior knee pain. One patient had full range of motion and a stable knee, but he reported anterior knee pain during activity. Four of the 8 patients with grade B femorotibial osteoarthritis mentioned pain and swelling during activities. In 1 patient with grade C generalized osteoarthritis, an acute ACL reconstruction was performed. Full range of motion and good stability of the knee

**TABLE 3**  
Outcomes of Clinical Evaluations

Knee Laxity Measurement	Hamstring Tendon Group		Patellar Tendon Group	
	n	%	n	%
Manual Lachman test				
A	22	79	22	85
B	5	18	3	12
C	1	3	1	3
Manual pivot-shift test				
A	23	83	21	81
B	4	14	4	16
C	1	3	1	3
International Knee Documentation Committee instrumental anteroposterior translation (KT-2000 arthrometer, 25° flexion) <sup>a</sup>				
A	22	80	21	82
B	5	17	4	15
C	1	3	1	3

<sup>a</sup>*P* = .646.

had been achieved, but he reported kneeling pain and swelling during activities. Three of 4 patients in the hamstring tendon group expressed kneeling pain and anterior knee pain during activities.

The IKDC score was based on the original IKDC evaluation method<sup>14</sup>; that is, it was not changed during the study period, considering the recent development of a questionnaire relating to "subjective" factors, to ensure uniformity of reporting during the 5-year period. Table 5 represents the distribution of patients according to overall IKDC score. Overall IKDC evaluation grade A was obtained in 50% (14/28) of patients in the hamstring tendon group and in 38% (10/24) of patients in the patellar tendon group. There was no statistically significant difference between groups (*P* = .692).

**DISCUSSION**

In a randomized controlled trial, we compared the use of the well-established and the most frequently used central-third bone–patellar tendon–bone autograft with use of a doubled semitendinosus and gracilis tendon autograft. Apart from the graft, all other important factors for the clinical outcome, such as fixation technique and the rehabilitation protocol, were identical. One surgeon performed all of the reconstructions, and unbiased observers, not involved in the operation or rehabilitation, performed the postoperative evaluations. The strength of this study is the fact that this is one of the longest known follow-up periods among controlled prospective

TABLE 4  
International Knee Documentation Committee Grading of Degenerative Joint Disease Comparing STG and PT Groups<sup>a</sup>

Knee Joint Arthritis	STG (5/28 patients, 17%)		PT (13/26 patients, 50%)	
	No. of Patients	Grade	No. of Patients	Grade
Patellofemoral	1	B	4	B
Femorotibial	2	B	6	B
Patellofemoral and femorotibial	2	B	2	B
			1	C

<sup>a</sup>STG, semitendinosus and gracilis tendon; PT, patellar tendon.  $P = .012$ .

TABLE 5  
Overall International Knee  
Documentation Committee Score<sup>a</sup>

IKDC Score	Hamstring Tendon Group		Patellar Tendon Group	
	n	%	n	%
A	14	50	10	38
B	13	47	15	59
C	1	3	1	3
D	0	0	0	0

<sup>a</sup> $P = .692$ .

comparative studies. Numerous studies have recently been published comparing patellar and hamstring tendon autografts in arthroscopic ACL reconstruction.<sup>4,8,10,17</sup> Many studies have been prospective, controlled, and randomized, but they were not able to compare patellar and hamstring tendon autografts alone because fixation techniques, surgical techniques, and rehabilitation protocols differed.<sup>9,12,17</sup> Thus, the present study continues to provide ongoing data showing the similarities and differences in the clinical results between the 2 groups.

The results of our study substantiate the similarities found in previous reports that document that good or excellent results may be obtained in the majority of ACL reconstructions when using either patellar tendon or hamstring tendon autografts. However, the study shows that there is a statistically significant difference according to the radiographic changes, possibly pointing to early osteoarthritis in patients from the patellar tendon group. In this study, 50% (13/26) of patients in the patellar tendon group and 17% (5/28) of patients in the hamstring tendon group had radiographic evidence of grade B osteoarthritis affecting the knee joint at 5 years after ACL reconstruction ( $P = .012$ ). An increased incidence of osteoarthritic change has been found after meniscal resection.<sup>1,30,31</sup> In this study, significantly more subtotal meniscal resections were performed in the hamstring tendon group ( $P = .027$ ); however, at 5-year follow-up, radiographic evidence of knee joint osteoarthritis was significantly elevated in patients from the patellar tendon group ( $P = .012$ ). This emphasizes the hypothesis that the choice of the graft is crucial in the

development of degenerative knee joint disease at 5 years after ACL reconstruction.

There has been only one prospective, long-term clinical study that compared hamstring tendon and patellar tendon autografts for ACL reconstruction. Roe et al<sup>28</sup> evaluated 2 groups of 90 patients each, consecutively treated with hamstring or patellar tendon grafts at 7 years after ACL reconstruction. In contrast to our study, in which all meniscectomies were included, their study eliminated all patients with more than one-third meniscectomy. In both studies, the patients with the contralateral ACL rupture and the patients who required revision surgery of the knee during the follow-up period were excluded. In contrast to our study, their study did not include patients with atraumatic graft failure. Both studies stated the overall rate of ACL ruptures, and neither of the studies found a significant difference in comparing the 2 different autografts. In contrast to our methods, the tibial graft fixation in Roe et al was performed with a metal RCI screw. Because that screw is made of metal, and not absorbable material, it is not appropriate to achieve the fixation of the graft at the tibial anatomical joint line. The removal of the metal screw, when revision of ACL surgery is required, could be a technically demanding procedure. Roe et al<sup>28</sup> found that patients with patellar tendon grafts had a greater prevalence of osteoarthritis at 7 years after surgery ( $P = .002$ ), which is in support of the results of our study.

Extension deficit was determined as the loss of extension in the involved limb in comparison with the passively maximally extended posture of the contralateral uninjured or "normal" limb. Historically, limitation of extension has been a significant problem after ACL reconstruction when using the central third of the patellar tendon. Early postoperative mobilization with emphasis on full passive extension has minimized extension loss. Pinczewski et al<sup>27</sup> reported that 31% of the patellar tendon group had a fixed flexion deformity and 19% of the hamstring tendon group had fixed flexion deformity at 5-year follow-up. Our results demonstrated no statistically significant difference in range of motion after hamstring tendon reconstruction compared with patellar tendon reconstruction. This study also confirmed that harvesting the semitendinosus and gracilis tendons or the middle third of the patellar tendon does not cause a permanent extension loss.

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. Marder et al<sup>20</sup> reported a 24% incidence of anterior knee pain in patients with either doubled semitendinosus and gracilis tendon or patellar tendon reconstructions. In contrast, our results are similar to those of Aglietti et al<sup>1</sup> and Anderson et al,<sup>2</sup> who found that anterior knee pain was only a minor problem. Donor-site symptoms do occur, but clear documentation of their origin is difficult because of problems with differentiating between the types of symptoms experienced. As determined by the IKDC evaluation, the number of donor-site symptoms in any form was minimal in both groups and statistically not significant. Kneeling pain was reported if it was present when patients kneeled on the carpeted floor. Roe et al<sup>28</sup> and Ejerhed et al<sup>8</sup> reported significant differences in kneeling pain comparing hamstring and patellar tendon groups, whereas the kneeling pain was greater in the patellar tendon group. In our study, these differences were not significant.

One of the key points of this study was the evaluation of objective stability after the reconstruction. At 5-year follow-up, objective anteroposterior knee stability was performed by using the KT-2000 arthrometer. No significant differences between 89-N and 134-N manual tension tests were observed. It appears that the manual maximum test is less reproducible than is the 20-lb (89-N) test, probably because of the higher effort that it involves. Furthermore, the rotatory alignment of the arthrometer is controlled only by hand on the patellar pressure pad because the other hand is used to pull the calf forward. However, 20 lb of force is often insufficient, particularly in the muscular or heavy patient. In these patients, the 30-lb (134-N) or the manual maximum test gives more stringent results.<sup>1</sup> Most investigations showed better static stability when a patellar tendon graft was used.<sup>1,2,8,9,26,27</sup> However, Wagner et al<sup>38</sup> found significantly fewer positive pivot-shift test results in the hamstring tendon group ( $P = .005$ ). The KT-1000 arthrometer side-to-side difference was 2.6 mm for the patellar tendon group and 2.1 mm for the hamstring tendon group ( $P = .041$ ). In our study, there was no significant difference between groups with respect to the Lachman or pivot-shift tests at 5 years. The mean value of objective anterior laxity measurements revealed no significant differences between the hamstring tendon and the patellar tendon group ( $P = .646$ ). Ferrari et al<sup>11</sup> compared clinical results between men and women after ACL reconstruction with the patellar tendon autograft. They did not find significant differences between the groups with respect to the Lachman and pivot-shift tests or failure rate. However, they found that the mean maximum side-to-side difference for men was  $0.76 \pm 2.8$  mm and  $1.73 \pm 2.2$  mm for women, which was statistically significant ( $P = .014$ ). In our study, we found that the mean 134-N side-to-side difference for men was  $1.1 \pm 2.4$  mm and for women  $2.4 \pm 1.9$  mm, which was also statistically significant ( $P = .031$ ).

The overall results of the present study, as measured by the IKDC evaluating system, were 97% normal or nearly normal in the hamstring and the patellar tendon groups. This result is high in comparison with the results of other prospective studies.<sup>2-4,8,10,17,28,31</sup> The overall IKDC results

in the present study may be so high because of the limited number of patients.

The other limitation in the design of our study is that there were meniscal injuries in addition to the ACL tear. It is difficult to obtain patients with solitary ACL tears without any other intra-articular lesions.

In conclusion, the results of our study substantiate the similarities found in previous reports that document that good or excellent results may be obtained in the majority of ACL reconstructions when using either patellar tendon or hamstring tendon autografts. Both hamstring and patellar tendon grafts provided good subjective outcomes and objective stability at 5 years. No significant differences in the rate of graft failure or contralateral ACL rupture were identified. Patients with patellar tendon grafts had a greater prevalence of osteoarthritis at 5 years after surgery.

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