A 7-Year Follow-up of Patellar Tendon and Hamstring Tendon Grafts for Arthroscopic Anterior Cruciate Ligament Reconstruction

Differences and Similarities

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Background: For arthroscopic anterior cruciate ligament reconstruction, the most commonly used graft constructs are either the hamstring tendon or patellar tendon. Well-controlled, long-term studies are needed to determine the differences between the 2 materials.

Hypothesis: There is a difference between hamstring and patellar tendon grafts in the clinical results of anterior cruciate ligament reconstructions at 7 years.

Study Design: Cohort study; Level of evidence, 2.

Methods: Two groups of 90 patients each, consecutively treated with hamstring or patellar tendon grafts, were followed and assessed at 1, 2, 5, and 7 years after surgery.

Results: At the 7-year review, abnormal radiographic findings were seen in 45% (24/53) of the patellar tendon group and in 14% (7/51) of the hamstring tendon group ($P = .002$). Although there was no significant difference between the groups in extension deficit ($P = .22$), the percentage of patients with an extension deficit increased significantly in the patellar tendon group from 8% at 1 year to 25% at 7 years ($P = .02$). No significant change was seen in the hamstring tendon group over time ($P = .20$). There was no significant difference in laxity between the groups on Lachman ($P = .44$), pivot-shift ($P = .39$), or instrumented ($P = .44$) testing. Graft rupture occurred in 4 patients from the patellar tendon group and in 9 patients from the hamstring tendon group ($P = .15$). Both autografts gave excellent subjective results, as evidenced by the International Knee Documentation Committee evaluation and Lysholm knee scores at 7 years.

Conclusions: Both hamstring and patellar tendon grafts provided good subjective outcomes and objective stability at 7 years. No significant differences in the rate of graft rupture or contralateral anterior cruciate ligament rupture were identified. Patients with patellar tendon grafts had a greater prevalence of osteoarthritis at 7 years after surgery; therefore, the authors preferred hamstring tendons as the primary graft choice in anterior cruciate ligament reconstructions.

Keywords: anterior cruciate ligament (ACL) reconstruction; hamstring tendon; patellar tendon; long term; clinical; longitudinal; prospective

Intra-articular reconstructions using either patellar tendon or hamstring tendon autografts are well-established techniques,[1,5,15,21] and studies have shown little difference between the 2 autografts in patient satisfaction and ligament stability outcomes at medium-term follow-up.[1,8,9,15,17] However, there is no clear consensus on which procedure or graft source is optimal, and this remains the subject of ongoing debate.[2,10] Our hypothesis was that there is a difference between the 2 graft materials and that this difference should affect the choice of graft in reconstructive surgery of the ACL.

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To compare 2 surgical techniques, extraneous variables need to be minimized by applying strict selection criteria. This study provides a prospective evaluation of a patient cohort with isolated ACL injury and continues the follow-up of patients previously reported.[17] We report the medium-term effects of ACL reconstruction on the knee joint and document the effect of graft choice on clinical outcome at 7 years after surgery.

MATERIALS AND METHODS

Patient Selection

The process undertaken for the inclusion of patients in this study group has been previously documented.[17] The patients were those who were originally enrolled, with no further additions. The selection of patients was based on the fulfillment of the study inclusion criteria and the absence of any exclusion criteria (Table 1).

Ethical committee approval was obtained from the Australian Institute of Musculo-Skeletal Research and Sydney University, and written informed consent was obtained from all patients.

Between January 1993 and April 1994, 90 patients undergoing ACL reconstruction with a patellar tendon graft (PT group) fulfilled the study inclusion criteria. The next 90 consecutive patients who underwent ACL reconstruction with a hamstring tendon graft and who fulfilled the same criteria were also entered into the study; these patients formed the comparison group (HT group). All patients undergoing ACL reconstruction during that time were considered for the study. Both groups of patients were treated with a similar rehabilitation program by the same group of physical therapists, and they had the same pain-relief protocol after surgery.

TABLE 1
Details of Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Endoscopic ACL reconstruction with either patellar tendon autograft or hamstring tendon autograft between January 1993 and November 1994	Any associated ligament injury requiring surgery Evidence of chondral damage or degeneration Previous meniscectomy Excision of >1/3 of one meniscus at time of reconstruction Abnormal radiograph result Abnormal contralateral knee joint Patients seeking compensation for their injury Patients who did not wish to participate in a research program

TABLE 2
Summary of Patient Demographics[a]

	Patellar Tendon Group	Hamstring Tendon Group
Male patients, n (right knees/left knees)	48 (29/19)	47 (22/25)
Female patients, n (right knees/left knees)	42 (25/17)	43 (16/27)
Median age, y (range)	25 (15-42)	24 (13-52)
Graft ruptures, n (%)	4 (4)	9 (10)
Contralateral ACL ruptures, n (%)	16 (18)	9 (10)
Patients available for review at 7 years		
With intact graft and contralateral ACL, n	70	73
With full clinical assessment, n (%)	59 (84)	61 (84)
With subjective assessment only, n	4	3
With radiographs, n	53	51

[a] n = 90 each for patellar tendon and hamstring tendon groups.

Surgical Technique

All procedures were performed by the senior author (L.A.P.) and have been described previously.[17] The grafts used to reconstruct the ACL were the ipsilateral middle-third patellar tendon or the 4-strand gracilis and semitendinosus tendons. A 7 × 25-mm titanium cannulated interference screw with an 8-mm rounded head (RCI, Smith & Nephew Endoscopy, Andover, Mass) was used for both proximal and distal graft fixation in both groups. The tunnel size in the PT group was determined as 1 mm larger than the bone block size, and in the HT group, the tunnel size equaled the cross-sectional diameter of the graft. This aspect of operative variability could not be minimized. No supplementary methods of fixation were used. A single-incision endoscopic technique was used with anteromedial and anterolateral arthroscopy portals and gravity-fed saline insufflation of the joint.

Rehabilitation

Immediately after surgery, patients began co-contractions of quadriceps and hamstring muscles as well as weight-bearing with the aid of crutches. No brace was used, and patients were encouraged to discard crutches as soon as possible. An accelerated rehabilitation program, focusing on achieving full extension by the 14th day after surgery, was instituted. Jogging was allowed after 6 weeks, but return to competitive sports was restricted until at least 6 months after surgery and only after knee stability had been reconfirmed on clinical examination.

Assessment

All patients were assessed before surgery, at 3, 6, and 12 months after surgery, annually for 5 years, and at 7 years by an independent examiner using the International Knee Documentation Committee (IKDC) evaluation form.[3]

TABLE 3
Complications and Further Surgery

	Hamstring Tendon Group			Patellar Tendon Group		
	No. of Patients	Mean Duration, mo	Range, mo	No. of Patients	Mean Duration, mo	Range, mo
ACL graft rupture	9	25	3-63	4	39	12-72
Contralateral ACL rupture	9	32	6-48	16	50	22-81
Meniscectomy	6	18	7-38	4	62	14-69
Contralateral meniscectomy	1	34		2	42	39-44
Excision of patellar tendinitis				1	24	
Removal of tibial screw	2	70	68-72	1	87	
Arthroscopy and arthrolysis				1	3	
Contralateral arthroscopy				1	36	
Arthroscopy and chondroplasty				1	21	
Spiral tibia and fibula fractures	1	24				
Removal of cyclops lesion	1	9		1	6	

Symptoms and signs of knee function were assessed to determine the IKDC grade.[3] The Lysholm knee score was obtained by a self-administered questionnaire.[11,22] Range of motion was measured using a goniometer. Clinical ligament testing was performed with Lachman, anterior drawer, and pivot-shift tests. Instrumented laxity testing results were determined with the KT-1000 arthrometer (MEDmetric Corp, San Diego, Calif) by measuring side-to-side differences in displacement on manual maximum testing. Pain from kneeling on a standard carpet surface and hamstring muscle discomfort were recorded for site and severity using a visual analog scale from 0 (no pain) to 10 (most severe pain). Before surgery and at 2, 5, and 7 years after surgery, weightbearing anteroposterior (AP), 30° flexion posteroanterior (PA), lateral, and 45° Merchant view radiographs were taken. The medial, lateral, and patellofemoral compartments were examined for evidence of any joint space narrowing and for the presence of osteophytes. The IKDC system (A, normal; B, minimal changes and barely detectable joint space narrowing; C, minimal changes and joint space narrowing of up to 50%; D, more than 50% joint space narrowing) was used for grading. This grading system does not differentiate between each compartment in the overall grade. An independent musculoskeletal radiologist who was blinded to the graft type interpreted each set of radiographs.

Statistical Method

The outcomes were compared between the 2 groups at 7 years using the Mann-Whitney *U* test for the continuous measurements (KT-1000 arthrometer, range of motion, Lysholm score) and ordered categorical variables (eg, IKDC categories). Changes over time were assessed with repeated-measures analysis. Linear regression analysis was used to assess the outcomes in different subgroups. Statistical significance was assessed at the 5% level.

RESULTS

The demographics of the patient groups have been previously reported[17] and are summarized in Table 2.

Those patients who suffered a graft rupture (n = 13) were excluded from further study regardless of whether they went on to have revision ACL surgery. However, 4 patients were included in the radiographic analysis at 7 years. Because the majority of the assessments assumed comparison with a normal contralateral limb, patients who sustained a contralateral ACL rupture during the study period were also excluded from the analysis.

Of the original 90 patients in the PT group, 70 had intact patellar tendon grafts and contralateral ACLs. At 7 years, 59 of these patients had a full clinical assessment, and an additional 4 had only a subjective evaluation. A total of 4 patients (4%) in this group had ruptured grafts, and 16 subjects (18%) sustained contralateral ACL ruptures.

In the HT group, 73 patients had intact hamstring tendon grafts and contralateral ACLs. At 7 years, 61 subjects had a full clinical assessment, and 3 had only a subjective evaluation. There were 9 cases (10%) of graft ruptures, and 9 patients (10%) ruptured their contralateral ACLs. These cases included 1 patient with both a graft rupture and a contralateral ACL rupture.

Of the 120 patients reviewed at 7 years (Table 2), radiographs were performed on 53 of 59 in the PT group and 51 of 61 in the HT group. Of the 16 patients without radiographic follow-up, 4 were pregnant and the remainder

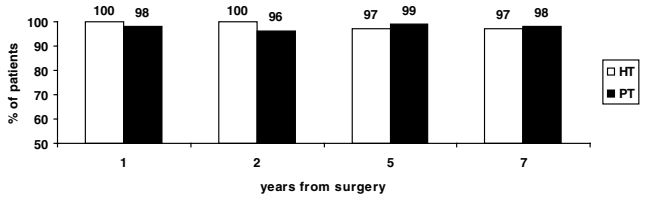

Figure 1. Percentage of patients with grade A or B subjective functional assessment. There was no significant difference between the patellar tendon (PT) and hamstring tendon (HT) groups at any time. There was no significant change over time.

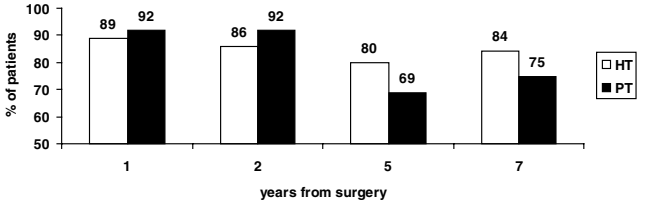

Figure 2. Percentage of patients with no extension deficit. There was no significant difference between the patellar tendon (PT) and hamstring tendon (HT) groups at 7 years (P = .22). In the HT group, there was no significant change in the percentage of patients with no extension deficit between 1 and 7 years (P = .20). In the PT group, there was a significant decrease in the percentage of patients with no extension deficit between 1 and 7 years (P = .02).

were reviewed at peripheral clinics without access to radiograph facilities.

Operative Findings

The ACL was reconstructed at less than 12 weeks after injury in 49 of 64 patients and 42 of 63 patients in the HT and PT groups, respectively (P = .46). Medial meniscal injury was noted at the time of reconstruction in 14 of 64 HT patients and 12 of 63 PT patients (P = .27). Lateral meniscal injury was observed in 30 of 64 HT patients and 21 of 63 PT patients (P = .11). The menisci were sutured in 5 patients from the HT group and in 4 patients from the PT group, and minimal resection of less than one third of the menisci was performed in 6 HT and 5 PT patients (P = .91).

Complications and Further Surgery

Statistically, there was no difference between the 2 groups in postoperative complications or further required surgery. In the PT group, 4 patients (4%) had graft ruptures, and 16 patients (18%) ruptured their contralateral ACLs. In the HT group, there were 9 cases (10%) of graft ruptures, and 9 patients (10%) ruptured their contralateral ACLs. There was no significant difference between the HT and PT groups in the rate of ACL graft rupture (P = .15) or contralateral ACL rupture (P = .13). Information concerning complications and further surgery is shown in Table 3.

Subjective Functional Assessment and Symptoms

There was no significant difference in subjective knee function (Figure 1) and symptoms of pain, swelling, and giving way at varying levels of activity between the 2 groups at any time.

Range of Motion

Extension deficit was determined as the loss of extension in the involved limb in comparison to the passively maximally extended posture of the contralateral uninjured or "normal" limb. Figure 2 details the percentages of patients in each group with no extension deficit at 1, 2, 5, and 7 years after surgery. No patient had an extension deficit of greater than 5°.

TABLE 4
Extension Deficit at 7 Years[a]

	Hamstring Tendon Group		Patellar Tendon Group	
	n	%	n	%
<3°	55	90	51	86
3° to 5°	6	10	8	14
>5°	0	0	0	0
Total	61	100.0	59	100.0

[a]There was no significant difference between the hamstring tendon and patellar tendon groups (P = .53).

In the PT group, the number of patients who developed an extension deficit increased between 1 and 5 years (P = .006) but did not change between 5 and 7 years (P = .50). In the HT group, there was no significant change over any time period. Table 4 depicts the graded extension deficit at 7 years.

CLINICAL LIGAMENT EVALUATION

Lachman and Pivot-Shift Testing

There was no significant difference between the groups with respect to the Lachman (P = .44) or pivot-shift (P = .39) tests at 7 years.

On Lachman testing, there was no significant change between 5 and 7 years in both the PT (P = .21) and HT groups (P = .91) (Figure 3).

On pivot-shift testing, there was no significant change between 5 and 7 years within the HT group (P = .71). In the PT group, however, there was a significant decrease in the percentage of patients with a grade 0, or normal, pivot-shift test result between 5 and 7 years (P = .03) (Figure 4).

Regression analysis revealed that female patients were significantly more likely than male patients to have

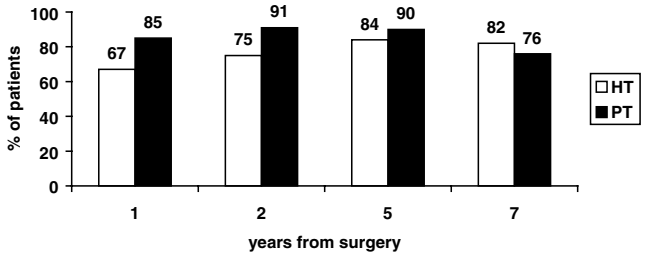

Figure 3. Percentage of patients with a grade 0 Lachman test result at each time point. There was no significant difference between the patellar tendon (PT) and hamstring tendon (HT) groups at 7 years (P = .44). In the HT group, there was a significant increase between 1 and 5 years (P = .05) and no change between 5 and 7 years (P = .91). In the PT group, there was no significant change between 1 and 5 years (P = .77) or between 5 and 7 years (P = .21).

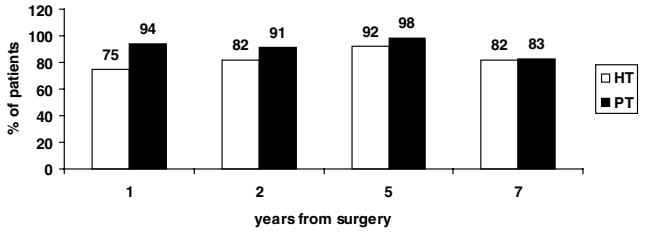

Figure 4. Percentage of patients with a grade 0 pivot-shift test result at each time point. There was no significant difference between the patellar tendon (PT) and hamstring tendon (HT) groups at 7 years (P = .39). In the HT group, there was a significant increase between 1 and 5 years (P = .03) and no change between 5 and 7 years (P = .71). In the PT group, there was no significant change between 1 and 5 years (P = .32) and a significant decrease in the percentage of patients with a grade 0 pivot-shift test result between 5 and 7 years (P = .03).

increased laxity on Lachman (P = .05) and pivot-shift testing (P = .02). Regression analysis also revealed a trend toward greater laxity in right-sided ACL reconstructions on pivot-shift testing (P = .06). This tendency was not significant on Lachman testing (P = .76). The variables of patient age or graft type did not significantly affect the outcome of Lachman and pivot-shift tests at 7 years.

Instrumented Testing

Figure 5 shows the percentage of patients in each group with a side-to-side difference in displacement of less than 3 mm on manual maximum testing for years 2 to 7. The findings at 7 years were similar to those at 5 years, with no significant difference between the groups. The number of patients with displacements of greater than 3 mm in the PT group was 15 of 59; in the HT group, it was 12 of 61. The PT group showed a trend toward an increasing number of displacements greater than 3 mm, whereas the HT group showed this number to be decreasing.

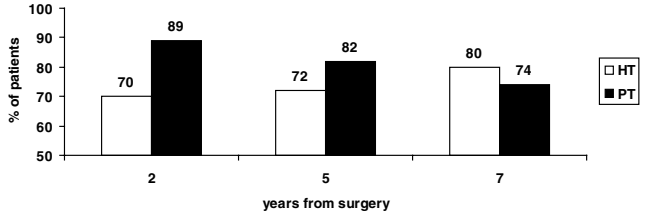

Figure 5. Percentage of patients with a side-to-side difference of less than 3 mm on KT-1000 arthrometer manual maximum testing. There was no significant difference between the patellar tendon (PT) and hamstring tendon (HT) groups at 7 years (P = .44). In the HT group, no significant change was found between 2 and 5 years (P = .18) or between 5 and 7 years (P = .44); however, there was a significant increase in this percentage between 2 and 7 years (P = .04). In the PT group, there was no significant change between 2 and 5 years (P = .21) or between 5 and 7 years (P = .41); however, there was a significant decrease between 2 and 7 years (P = .03).

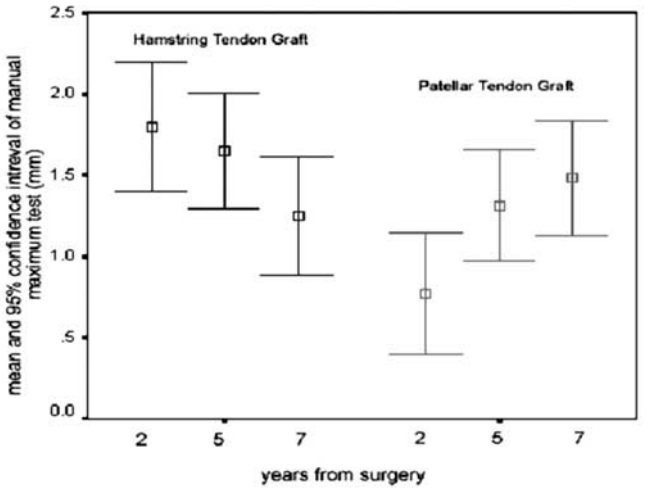

Figure 6. Means and 95% confidence intervals for the side-to-side difference in manual maximum laxity testing by KT-1000 arthrometer at 2, 5, and 7 years from surgery. Data for the hamstring tendon (HT) group are shown on the left, and those for the patellar tendon (PT) group are shown on the right; the squares represent the means, and the top and bottom lines represent the 95% confidence intervals. Similar to the 5-year findings, there was no significant difference between the HT and PT groups at 7 years (P = .26). The mean difference in manual maximum laxity decreased significantly in the HT group between 2 and 7 years (P = .005) and increased significantly in the PT group between 2 and 7 years (P = .03).

The means and 95% confidence intervals for the manual maximum laxity test are shown in Figure 6. The discrepancy seen between the groups at 2 years subsequently normalized at 5 years because of increased laxity developing in the PT group (0.8 mm at 2 years, 1.3 mm at 5 years; P = .01) and decreased laxity developing in the HT group (1.8 mm at 2 years, 1.7 mm at 5 years; P = .18). In the HT

TABLE 5
IKDC Grade of Radiographs at 2, 5, and 7 Years After Surgery in Patellar Tendon and Hamstring Tendon Groups[a]

	Patellar Tendon Group				Hamstring Tendon Group				
	n	Grade A	Grade B	Grade C	n	Grade A	Grade B	Grade C	*P*
2 years after surgery	72	68 (94)	4 (6)		67	67 (100)			.05
5 years after surgery	61	43 (70)	18 (30)		46	41 (89)	5 (11)		.02
7 years after surgery	53	29 (55)	22 (41)	2 (4)	51	44 (86)	6 (12)	1 (2)	.002

[a]IKDC, International Knee Documentation Committee; IKDC grade A = normal; grade B = minimal changes and barely detectable joint space narrowing; grade C = minimal changes and joint space narrowing of up to 50%; grade D = more than 50% joint space narrowing. Values in parentheses indicate percentages.

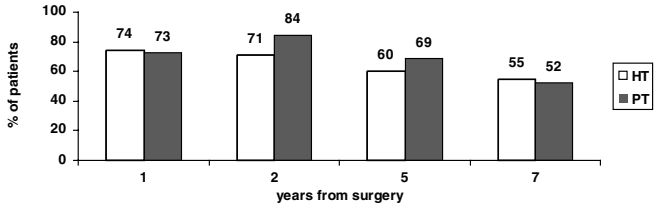

Figure 7. Percentage of patients participating in International Knee Documentation Committee level 1 or 2 activities (those that involve cutting, pivoting, or sidestepping). There was no significant difference between the hamstring tendon (HT) and the patellar tendon (PT) groups at 7 years (P = .79). Both groups displayed a significant decrease in activity level between 1 and 7 years (P < .05). The decrease in activity level between 5 and 7 years reached significance in the PT group only (PT, P = .03; HT, P = .24).

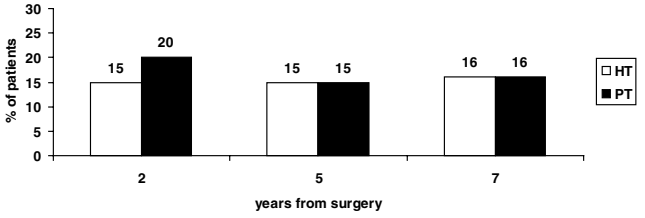

Figure 8. Percentage of patients who reported a knee-related decrease in activity. There was no significant difference between the hamstring tendon (HT) and the patellar tendon (PT) group and no significant change over time.

group, the mean laxity decreased further to 1.3 mm at 7 years, which was a significant decrease compared to the 2-year result (P = .005). In the PT group, the mean laxity increased to 1.5 mm at 7 years, a significant increase compared to the 2-year result (P = .03). Analysis at 7 years did not show any statistically significant differences between the PT and HT groups (P = .26).

Radiographic Assessment

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. Patients with abnormal radiographs before surgery were excluded from the study. Radiographic assessment was performed on 139 patients at 2 years, 102 patients at 5 years, and 104 patients at 7 years. The data at 7 years included 2 graft ruptures each from the PT and HT groups. All of these patients went on to have revision procedures. The results are shown in Table 5. Radiographic evidence of knee joint osteoarthritis was present in 45% (24/53) of patients in the PT group and in 14% (7/51) of patients in the HT group (P = .002).

Regression analysis revealed that Lachman and instrumented testing, gender, activity level at 2 years, and extension loss at 2 years were not associated with abnormal radiographic examination results at 7 years. Abnormal radiographic findings were associated with patients with a patellar tendon graft (P = .001) and patients with less laxity on manual maximum testing (P = .02). Abnormal radiographic examination results were seen in 24 of 53 PT patients and 7 of 51 HT patients, and in 24 of 67 patients with a difference in displacement of less than 3 mm on manual maximum testing and 3 of 15 patients with a difference of 3 to 5 mm.

Activity Level

As previously identified in the 5-year study,[17] there is a trend toward a reduction of activity level after ACL surgery, and this tendency continued up to the 7-year point and is summarized in Figure 7. As in previous years, less than 20% of patients reported that they decreased their activity level because of their knee (Figure 8).

At 7 years, 52% (33/63) of patients in the PT group and 55% (35/64) of patients in the HT group were participating in strenuous or moderate activities (P = .79).

Overall IKDC Score

The IKDC score was based on the original IKDC evaluation method;[3] that is, it was not changed during the study period, considering the recent development of a questionnaire relating to "subjective" factors,[16] to ensure uniformity of reporting during the 7-year period. Figure 9 shows the percentages of patients in each group with an overall IKDC grade A or B for each review point. There was no sig-

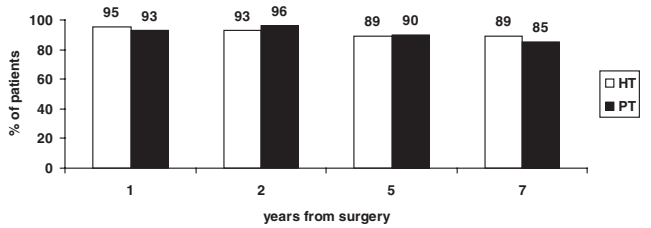

Figure 9. Percentage of patients with an overall International Knee Documentation Committee score of A or B at each time point. There was no significant difference between the hamstring tendon (HT) and the patellar tendon (PT) groups, and there was no significant change over time.

nificant difference between the 2 groups at 7 years, as shown on review at earlier time periods.[17]

More than 85% of patients in both groups had grades of either A or B throughout the review period. There was no significant change over time in either group.

Patient age, sex, or graft type had no effect upon the overall IKDC score at 7 years. The overall IKDC score at 1 year had a statistically significant effect ($P = .001$) on the score at 7 years. Ninety percent of patients with a grade A or B at 1 year also had a grade A or B at 7 years.

Lysholm Knee Score

In the HT group, the mean Lysholm knee score was 93 at 2 years (SD = 10.0), 94 at 5 years (SD = 8.7), and 93 at 7 years (SD = 8.6). In the PT group, the mean Lysholm knee score was 94 at 2 years (SD = 8.3), 94 at 5 years (SD = 7.9), and 93 at 7 years (SD = 9.0). There was no significant change over time in either the HT ($P > .76$) or the PT ($P > .48$) groups. There was no significant difference between the HT and PT groups at years 2 ($P = .77$), 5 ($P = .91$), or 7 ($P = .93$).

Kneeling Pain

Kneeling pain was reported if it was present after patients kneeled on a carpeted floor for approximately 2 minutes' duration. The severity was recorded on a visual analog scale from 0 to 10.

At 7 years, there continued to be a significant difference in kneeling pain between the 2 groups, with 54% (34/63) of patients in the PT group and 20% (13/64) of patients in the HT group reporting such pain ($P < .001$). This difference between the groups was the greatest observed at any time outside the first year of follow-up.

When the severity of the kneeling pain was considered, there was a significant difference between the median score in the HT (0) and the PT (2.0) groups ($P < .001$, Mann-Whitney U test). For those patients who had kneeling pain, the median intensity recorded was 5 for the PT group and 3 for the HT group ($P = .13$, Mann-Whitney U test).

Donor Site Symptoms at Rest

According to the IKDC form, patients were asked to report both the presence and severity of donor site symptoms (tenderness, irritation, or numbness) while at rest. At 7 years, 38% (24/63) of patients in the PT group and 14% (9/64) of patients in the HT group reported symptoms from their graft site ($P = .01$). At 7 years, no patient from the HT group graded their symptoms as greater than mild, but 4 patients in the PT group graded their symptoms as moderate and 1 patient graded his symptoms as severe.

DISCUSSION

This prospective, nonrandomized clinical trial of patients with patellar tendon and hamstring tendon grafts for arthroscopic ACL reconstruction has shown that between graft materials there is a difference that affects clinical results at 7 years. This difference can be seen in the radiographic grading, possibly pointing to the early onset of osteoarthritis in patients in the PT group, but as shown during earlier follow-up, it cannot be seen in overall IKDC scores. The PT group also displayed an increasing loss of terminal extension, an increasing percentage of patients with greater than 3 mm of side-to-side difference on instrumented testing, and a decreasing percentage of patients with a grade 0 pivot-shift test result over time. The differences in clinical ligament testing and instrumented testing at 7 years, however, were not significant between the PT and HT groups.

The need for prospective, long-term studies comparing the 2 grafts with identical surgical techniques, solitary ACL tears, and accelerated rehabilitation methods[4,6-8,12,19] has been identified. Numerous studies have recently been published comparing patellar and hamstring tendon autografts in arthroscopic ACL reconstruction.[4,6-8,12,19] Many studies have been prospective, controlled, and also randomized, but they have not all been able to compare patellar and hamstring tendon autografts alone because fixation techniques, surgical techniques, and rehabilitation protocols have been different.[7,10,12] Thus, this study continues to provide ongoing data showing the similarities and differences in the clinical results between the 2 groups.

In this study, 45% (24/53) of patients in the PT group and 14% (7/51) of patients in the HT group had radiographic evidence of osteoarthritis affecting the knee joint at 7 years after ACL reconstruction ($P = .002$). Regression analysis revealed that patients treated with a patellar tendon graft were associated with an abnormal radiographic examination result ($P = .001$), despite the restoration of joint stability observed with both grafts. In previous studies, both grafts have been shown to be equally effective at preventing instability, with no difference reported in terms of ligament stability, range of motion, and general symptoms during early follow-up.[1,5,14,15,21] But, to date, studies comparing patellar tendon and hamstring tendon grafts have not been performed with an adequate period of follow-up to investigate the development of arthrosis, even in its early stages. The development of arthrosis has been documented in this cohort of patients.

Shelbourne and Gray[20] believed that damage in the knee joint does not seem to affect the knee until approximately 7 years after surgery and therefore advised that long-term follow-up should be performed consistently at

10, 15, and 20 years after the ACL reconstruction. This study provides data at the 7-year mark after ACL reconstruction and demonstrates early evidence of arthrosis associated with the type of graft used for the reconstruction. In contrast to Shelbourne and Gray's[20] findings, which were not based on radiographic follow-up, the data in this study show that ACL reconstruction surgery using patellar tendon autografts is associated with a higher prevalence of arthrosis when compared to hamstring tendon grafts.

Despite evidence that intact menisci result in the lowest incidence of degenerative change[13] after ACL reconstruction, the natural history of osteoarthritis after endoscopic ACL reconstruction remains unknown. The patient population in this study provided an opportunity to look at the effect of ACL reconstruction using 2 graft types on the development of knee osteoarthritis over the medium term.

When considering the differences between the 2 grafts, the presence of an extension deficit in a slowly increasing number of patients between 1 and 7 years in the PT group (P = .02) may clinically reflect the early signs of osteoarthritis. Previous authors have reported this difference as objective[7] and subjective[4] findings. In this study, the extension deficit was not reported subjectively but was objectively found to have increased in number in the PT group. The magnitude of the deficit was not significant.

The limitation of this study not being randomized has been addressed previously.[17] It is well recognized that a prospective randomized clinical trial should provide the ideal environment for the comparison of 2 graft materials in ACL reconstruction surgery. This prospective cohort study, therefore, has this limitation. The majority of complicating factors have been removed, however, allowing a prospective comparison between hamstring and patellar tendon autografts. Identical surgical techniques using RCI screw fixation, performed by a single surgeon over a short period of time, have been compared. Validated outcome measures have been used, including a radiographic analysis by a single independent observer. The number of radiographs reviewed at 7 years is less than the number of patients who underwent full clinical assessment because radiograph services were unavailable at the place of follow-up or because patients refused repeated radiographic evaluation for a number of reasons, including pregnancy in 4 patients. Statistical evaluation using regression analysis revealed that abnormal radiographic findings were associated with a patellar tendon autograft.

When considering the issue of selection bias, one must consider whether the groups differed in measured or unmeasured baseline characteristics because of the way participants were assigned to each group. Our inclusion criteria were based on the presence of ACL insufficiency confirmed on clinical examination and the inability to return to the desired functional level.[17] Strict exclusion criteria were established that prevented confounding variables in the 2 patient groups, and patients were selected prospectively, in 2 cohorts, based on the time at which they were evaluated for reconstructive surgery.

This study confirms that subjective functional results, as measured by the Lysholm knee score and the presence of symptoms (pain, swelling, and giving way), and objective results, as measured by the IKDC score, after ACL reconstruction using either autograft are equal at 7 years. Freedman et al, however, found that a longer follow-up period provided support "for the conclusion that a patella tendon autograft is more likely to result in a functionally stable knee."[10(p5)] In our cohort, more than 85% of patients at 7 years had a normal or nearly normal knee after ACL reconstruction, irrespective of the type of graft used. The overall IKDC score at 1 year had a statistically significant effect (P = .008) on the score at 7 years, although there was no significant change in score over time. Although ACL graft rupture occurred in 9 hamstring tendon patients and 4 patellar tendon patients during the 7-year follow-up period, the difference was not statistically significant (P = .15). However, further study in this area with greater power is warranted and is currently in press.[18] Other clinical outcomes such as further arthroscopic surgery and contralateral injury were also not significantly different in either group. The subjective and objective results should therefore emphasize the similarities in the 2 autografts.

There was a significant difference at 7 years in the presence of kneeling pain and donor site symptoms between the 2 graft types. This finding has been reported in previous studies, but symptoms have not been shown to persist at 7 years.[6-8,19] This study found that kneeling pain was a problem with the patellar tendon graft. At 7 years, 54% of patients with patellar tendon grafts complained of pain from kneeling, compared with 20% of patients with hamstring tendon grafts (P < .001). There was also a significant difference in mean severity of the kneeling pain between the 2 groups (P < .001). This trend has been identified before,[17] with an increase in the percentage of patients who reported kneeling pain with time, and for all time points, which was significantly worse with patellar tendon grafts.

Donor-site symptoms do occur, but clear documentation of their origin is difficult because of problems with differentiating between the types of symptoms experienced.[17] As determined by the IKDC evaluation,[3] the number of donor-site symptoms in any form in the PT group was more than double that of the HT group (P = .01).

Although there were similarities in the laxity measurements between the 2 graft types at 7 years, between the 2- and 7-year review period, there was a statistically significant decrease in mean laxity as determined by KT-1000 arthrometer testing in the HT group (1.8 mm at 2 years to 1.3 mm at 7 years, P = .005). Seventy percent of the HT group had less than 3 mm laxity at 2 years compared to 80% at 7 years (P = .04). The PT group demonstrated an increase in laxity from 0.8 mm at 2 years to 1.5 mm at 7 years (P = .03). The differences seen in the laxity measurements over time may reflect a remodeling process that occurs in the graft over time. Weiler et al[23] reported the presence of myofibroblasts in sheep ACL tendon grafts after reconstruction. These cells may explain the paradoxical tightening of the hamstring tendon grafts observed in this series, although one can only speculate on the increase in laxity seen in the patellar tendon grafts.

CONCLUSION

We have shown that between graft materials used in arthroscopic ACL reconstruction, there is a difference that affects clinical results at 7 years. The development of early radiographic osteoarthritis in the PT group identified in the 5-year study has been confirmed in the present study. This finding, combined with changes in ligament evaluation and extension deficit over time in the PT group, provides data to favor the hamstring tendon autograft over the patellar tendon autograft. Ipsilateral hamstring tendon grafts appear to become significantly tighter over 7 years, and patellar tendon grafts develop increased laxity. The reasons for this trend remain uncertain and require further investigation. Considering the similarities between the grafts at 7 years, however, this study provides further confirmation that surgical reconstruction with either the patellar tendon autograft or hamstring tendon autograft restores knee stability and allows a return to a high level of functional activity.

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