

Gender Differences in Outcome After Anterior Cruciate Ligament Reconstruction With Hamstring Tendon Autograft

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Background: It is now well documented that women are more likely to suffer anterior cruciate ligament injuries than are men. A few studies have examined gender differences in the outcome of anterior cruciate ligament reconstruction with patellar tendon graft and hamstring tendon with EndoButton fixation, but no well-controlled studies have specifically compared men and women after anterior cruciate ligament reconstruction with hamstring tendon graft and interference screw fixation.

Hypothesis: There is no difference in outcome between men and women after anterior cruciate ligament reconstruction with hamstring tendon autograft and interference screw fixation.

Study Design: Cohort study; level of evidence, 3.

Methods: There were 100 men and 100 women who underwent isolated anterior cruciate ligament reconstruction by a single surgeon. Patients were assessed preoperatively and at 1, 2, and 7 years after surgery. Variables were compared between female and male patients.

Results: Laxity on physical evaluation was greater in women than in men on Lachman ($P = .04$), pivot-shift ($P = .05$), and mean manual maximum testing ($P = .05$) at 7 years. However, the magnitude of this difference was small. No patient had a greater than grade 1 Lachman or pivot-shift test result, and the mean difference between men and women was 0.6 mm on instrumented testing. Anterior cruciate ligament graft rupture occurred in 11 men and 10 women. There was no difference between male and female patients for self-reported knee function or symptoms of instability or radiologic examination.

Conclusion: Anterior cruciate ligament reconstruction using hamstring tendon autograft affords excellent self-reported and objective results in both men and women after 7 years. Although significantly greater laxity on physical examination was present in female patients than in male patients, the magnitude of this difference was small and had no effect on activity level, graft failure, or subjective or functional assessment.

Keywords: anterior cruciate ligament (ACL); reconstruction; gender; laxity; hamstring

There is now clear evidence that women are 2 to 8 times more likely to suffer an ACL injury than are men.^{1,3,16} With this finding, there has been increasing interest examining gender-based differences over recent years. There are studies that have specifically examined gender differences after ACL reconstruction with bone-patellar tendon-bone grafts^{5,12} or hamstring tendon with EndoButton fixation²⁴;

yet to date, there have been no studies specifically examining gender-based differences in outcome after ACL reconstruction with hamstring tendon graft and interference screw fixation.

A difference in laxity between men and women after ACL reconstruction with hamstring tendon autograft was first reported by Corry et al.⁸ They compared 180 patients 2 years after ACL reconstruction with either patellar tendon or hamstring tendon autograft and found that female patients with hamstring tendon grafts had greater laxity on KT-1000 arthrometer testing than did female patients with patellar tendon grafts ($P = .001$) and male patients with either hamstring tendon ($P < .0001$) or patellar tendon grafts ($P = .0003$). However, the primary aim of this article was a comparison between hamstring tendon and patellar tendon grafts; the gender difference found on laxity assessment was a secondary finding.

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Subsequent studies have been performed examining gender differences after ACL reconstruction in more detail.^{5,12,24} Noojin et al²⁴ examined 39 male and 26 female patients after ACL reconstruction with autogenous hamstring tendon and EndoButton fixation at a mean follow-up of 40 months. When compared with the male subjects, female subjects had greater laxity, higher failure rates, and higher frequency and intensity of pain. Gobbi et al¹⁵ also examined gender differences after hamstring tendon ACL reconstruction with EndoButton fixation in a series of 26 men and 14 women. They reported greater laxity in the female patients and no significant differences on graft rupture rates, self-reported outcome, or functional assessments. Others examining gender differences after ACL reconstruction with patellar tendon autograft have reported no significant differences in outcome between the male and the female patients.^{5,12}

To accurately compare men and women after ACL reconstruction, confounding factors that may affect outcome should be controlled. Significant gender differences have been reported in the incidence and severity of meniscal and/or articular cartilage damage associated with ACL injury.^{3,26} Meniscal damage or resection has been shown to adversely affect self-reported results and laxity testing.^{18,29} In addition, in a cadaveric study, Papageorgiou et al²⁵ have shown that the in situ forces on the ACL graft are 33% to 50% higher in the absence of the medial meniscus, which may subject the ACL graft to higher risks of failure. It is therefore essential to control for these factors when comparing gender outcomes. Previous studies examining gender differences after ACL reconstruction have failed to control for concurrent injuries^{5,24} and did not use a standardized operative technique for all patients, which may have confounded the results.

The current study controlled for these confounding factors by including only patients without articular cartilage injury and no more than one-third meniscal excision. In addition, we minimized the potential bias of other variables that may influence outcome by reviewing patients from a single surgeon, using the same surgical technique and fixation methods, and the same postoperative rehabilitation program in a large group of patients. The primary variable we investigated was gender, with all other variables being matched between the 2 groups.

It has been shown that greater clinical ligament laxity does not necessarily translate to poorer perceived results or function. Recently, Kocher et al¹⁹ reported that subjective symptoms and function had no relationship with Lachman and instrumented testing but were related to pivot-shift testing in their assessment of 202 patients. Others have also reported significant differences in laxity testing that did not correlate with perceived or functional assessments.^{6,17,23} Currently, many clinicians emphasize the importance of clinical ligament stability; however, in the absence of pathologic clinical laxity (eg, grade 2 Lachman or pivot result), it can be argued that the patients' perceived symptoms and functional ability to participate in desired activities are paramount.

In this study, we present a detailed comparison between 100 men and 100 women 7 years after ACL reconstruction with a quadrupled hamstring tendon graft and interference screw fixation. Our primary aim was to examine the effect

of gender on clinical ligament laxity and perceived and functional outcomes. We also sought to examine the relationship between laxity testing and self-reported and functional results.

MATERIALS AND METHODS

Subjects

The first consecutive 100 men and 100 women undergoing ACL reconstruction by the senior author (L.A.P.) between October 1993 and March 1996 with hamstring tendon autograft and interference screw fixation and who met the inclusion criteria formed the study group. Ethics approval for this study was granted by the University of Sydney. We excluded subjects with any of the following: (1) any associated ligament injury requiring surgical treatment, (2) evidence of chondral damage or degeneration, (3) previous meniscectomy, (4) excision of more than one third of one meniscus at the time of reconstruction, (5) an abnormal radiograph finding, (6) any abnormality in the contralateral knee, (7) those patients seeking compensation for their injuries, and (8) those who did not wish to participate in a research program. The sample size of 200 yielded a power of greater than 0.8 to detect a 15% variation between groups in results, with a significance level of 5%. The adjusted power for the 143 patients reviewed at 7 years based on the ability to detect a 15% variation between groups in results, with a significance level of 5%, was 0.78.

The diagnosis of primary ACL deficiency was based on a detailed history of the knee injury, clinical examination with pathologic laxity, and the findings at surgery. Plain radiographs were obtained in all patients preoperatively, but MRI scans were not routinely performed. All associated injuries were documented at the time of operation. Indications for reconstruction were (1) acute injuries in young patients, (2) acute injuries in those desiring to return to cutting or side-stepping sport, or (3) chronic injuries with persistent instability while performing sporting or activities of daily living without significant radiographic evidence of knee degeneration. Reconstruction was performed once the knee had recovered from the acute trauma of the ACL injury and patients had a pain-free, mobile joint.

Surgical Technique

All operations were performed by the senior author (L.A.P.) with the patient under general anesthesia and tourniquet. The surgical technique has been previously reported in detail.⁸ A "single-incision" endoscopic technique was used. All patients' knees were reconstructed with a 4-strand hamstring graft. Femoral drilling was performed via the anteromedial portal. Fixation was achieved with the 7 × 25-mm RCI interference screw in the femoral and tibial tunnels.

Postoperative Rehabilitation

Patients were permitted to bear weight as tolerated on crutches immediately after surgery. They were given oral

analgesics for pain control and daily physical therapy to reduce postoperative swelling and to allow active exercises aiming for full extension by 14 days. No brace was used. The intensive rehabilitation program included closed-chain exercises and an emphasis on proprioceptive training. At 6 weeks, patients began jogging in straight lines and swimming. From 12 weeks, general strengthening exercises were continued, with agility work and sports training activities encouraged. Return to competitive sport involving jumping, pivoting, or side stepping was prohibited until 6 months after the reconstruction and only after rehabilitation goals had been met.

Assessment

Patients were assessed preoperatively and at 12, 24, and 84 months after surgery using the International Knee Documentation Committee (IKDC) evaluation form.² Assessment was performed by either a physical therapist or a clinical researcher with extensive experience in knee assessment. Ligament stability was assessed by the Lachman³² and pivot-shift tests.¹⁴ The Lachman test was graded as 0 (less than 3 mm), 1 (3-5 mm), or 2 (more than 5 mm) and the pivot-shift test as 0 (negative), 1 (glide), 2 (clunk), or 3 (gross). Instrumented knee testing was performed using the KT-1000 arthrometer (MEDmetric Corp, San Diego, Calif) manual maximum test at 30° of flexion. Patients rated pain intensity on a 0 to 10 scale when kneeling on a carpeted surface. The level of sporting activity was assessed according to the IKDC levels I to IV, that is, I, strenuous (rugby, basketball); II, moderate (skiing, tennis, heavy manual labor); III, light (jogging); and IV, sedentary. Patients completed the Lysholm knee score³¹ to document subjective symptoms.

Before surgery and at 2 and 7 years after surgery, weightbearing AP, 30° flexion posteroanterior, lateral, and patellofemoral view radiographs were taken. The medial, lateral, and patellofemoral compartments were examined for evidence of joint space narrowing and the presence of osteophytes. The IKDC system is a simple yet reliable tool using definitions incorporating both osteophytes and joint space narrowing, which is the most reproducible method of documenting longitudinal radiographic data.²² Using the IKDC system, we graded the radiographs as A, normal; B, minimal changes and barely detectable joint space narrowing; C, moderate changes and joint space narrowing of up to 50%; and D, severe changes and more than 50% joint space narrowing. All radiographs were interpreted by an independent musculoskeletal radiologist.

Statistical Analysis

The outcomes were compared between men and women at 7 years after surgery using the Mann-Whitney *U* test for the continuous measurements (mean KT-1000 arthrometer, range of motion, and Lysholm score) and the χ^2 test for ordered categorical variables (such as IKDC categories, Lachman, and pivot-shift test). Logistic regression analysis was used to assess the relationship between the laxity assessments and the variables of gender, graft size, and index side. Logistic regression was also used to examine the

relationship between radiologic outcomes and the variables of age, gender, extension loss at 2 years, and Lachman test result at 2 years. Statistical significance was set at the 5% level.

RESULTS

Two hundred patients were included in the study. By 7 years after surgery, 21 (11%) patients had a graft rupture, and 12 patients had a contralateral ACL rupture (6%), including 1 patient who suffered both an ACL graft rupture and a contralateral ACL rupture. The ACL graft rupture occurred in the first 6 months in 2 women and 1 man while participating in activities against the surgeon's advice (dancing the twist while intoxicated at 2 months and touch football and, a noncontact form of rugby at 2 and 5 months, respectively). The remaining 18 graft ruptures occurred during sporting activities. Nineteen of the 21 patients with a graft rupture proceeded to revision ACL reconstruction. Of these, 3 men had another injury resulting in rupture of their revision ACL grafts. There was no significant difference between men and women in the rate of graft rupture ($P = .97$) or contralateral ACL rupture ($P = .32$). Further details on complications are shown in Table 1.

Patients who had an ACL graft rupture were excluded from further analysis in this study as the majority proceeded to revision surgery. One additional patient was excluded who had suffered a complete posterior cruciate ligament rupture, confirmed by MRI scan at 64 months after surgery. Therefore, by 7 years after surgery, 178 of the original 200 patients remained in the study group. Assessment was performed on 164 (92%) at 1 year, 153 (86%) at 2 years, and 143 (80%) at 7 years. Of the remaining 35 patients not reviewed at 7 years, 20 were unable or unwilling to attend, 10 were residing outside Australia, and 5 could not be located.

Of the 143 patients seen at 7 years, there were 70 women and 73 men. There was no significant difference between women and men for the variables of age ($P = .16$), injured side ($P = .67$), timing of surgery ($P = .19$), or meniscal status at the time of surgery ($P = .96$). The mean hamstring graft size was 6.6 mm in the women and 7.0 mm in the men. This difference was statistically significant ($P = .001$). A summary of results is shown in Table 2.

Ligament Laxity

Ligament laxity was assessed with the Lachman, pivot-shift, and KT-1000 arthrometer instrumented testing.

Lachman Test. On Lachman testing, women had significantly greater laxity than did men at 1 ($P = .03$), 2 ($P = .003$), and 7 years ($P = .04$) after surgery (Figure 1). There were no patients with a Lachman test result greater than grade 1. There was no significant change over time in either male or female patients.

Pivot-Shift Test. On pivot-shift testing, women had significantly greater laxity than did men at 1-, 2-, and 7-year assessments (Figure 2). In the male patients, the percentage of patients with a grade 0 pivot-shift result increased

TABLE 1
Details of Patient Complications and Subsequent Injuries After ACL Reconstruction

Complications	Women		Men	
	No. Patients	Mean Time, mo (range)	No. Patients	Mean Time, mo (range)
ACL graft rupture	10	30 (2-63)	11	21 (3-47)
Contralateral ACL rupture	4	51 (23-81)	8	32 (6-71)
Meniscectomy	4	17 (7-36)	7	31 (14-60)
Removal of cyclops lesion	1	9	4	28 (6-80)
Inflammatory synovitis requiring synovectomy	1	29		
Posterior cruciate ligament rupture			1	64
Removal of ganglion cyst	1	68		

TABLE 2
Summary of Results at 7 Years

Variable	Women	Men	P
No. patients	70	73	
Mean KT-1000 arthrometer, mm	1.9	1.3	.02 ^a
Grade 0 Lachman, %	68	83	.04 ^a
< 3° extension loss, %	92	85	.13
Lysholm median	95	95	.99
Hop test grade A or B, %	74	85	.30
Overall International Knee Documentation Committee grade A or B, %	86	89	.65
Grade A radiograph (n = 103), %	90	78	.09

^aDenotes statistically significant difference.

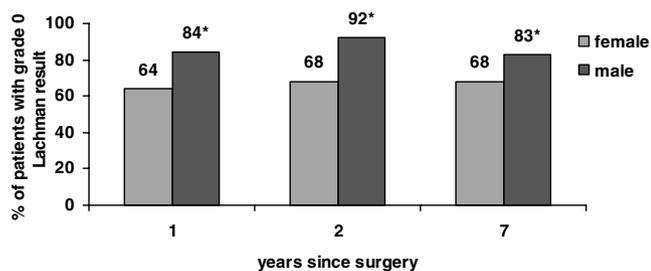


Figure 1. Percentage of patients with a grade 0 Lachman result at each time point. Significantly more male than female patients had a grade 0 Lachman result at 1 ($P = .03$), 2 ($P = .003$), and 7 years ($P = .04$) after surgery. *Denotes significant difference.

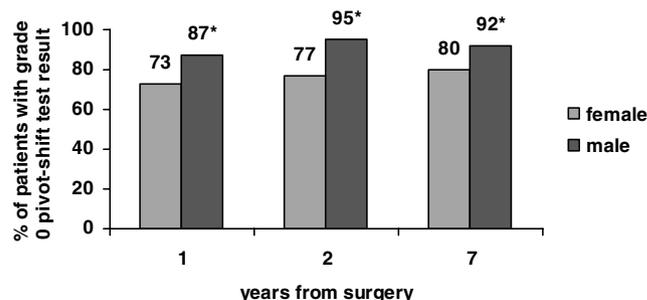


Figure 2. Percentage of patients with a grade 0 pivot-shift test result at each time point. Significantly fewer female than male patients displayed a grade 0 pivot result at 1 ($P = .05$), 2 ($P = .004$), and 7 years ($P = .05$) after surgery. *Denotes significant difference.

significantly between 1 and 2 years ($P = .01$). There were no other significant differences in men or women over time. There were no patients with a pivot-shift test result greater than grade 1.

Instrumented Testing. Instrumented testing was performed with the KT-1000 arthrometer at 1-, 2-, and 7-year review. Those patients with contralateral ACL injury were excluded from instrumented testing, which assumes a normal contralateral limb. Testing was performed on both the reconstructed and the normal contralateral limb, and side-to-side differences are reported. Testing was performed on 150 patients at 1 year, 156 patients at 2 years, and 125 patients at 7 years. The mean, median, and 95%

confidence intervals for men and women are shown in Figure 3. There was a significant increase in the mean side-to-side difference between 1 and 2 years in the female patients ($P = .02$) and no change between 2 and 7 years. There was no significant change over time in the male patients.

At 1 and 2 years, there were significantly more women than men with a side-to-side manual maximum difference of more than 3 mm ($P = .02$ at 1 year, and $P = .03$ at 2 years). At 7 years, this trend was present but did not reach significance ($P = .09$). There was no significant change over time in the percentage of men or women with a manual maximum test result less than 3 mm.

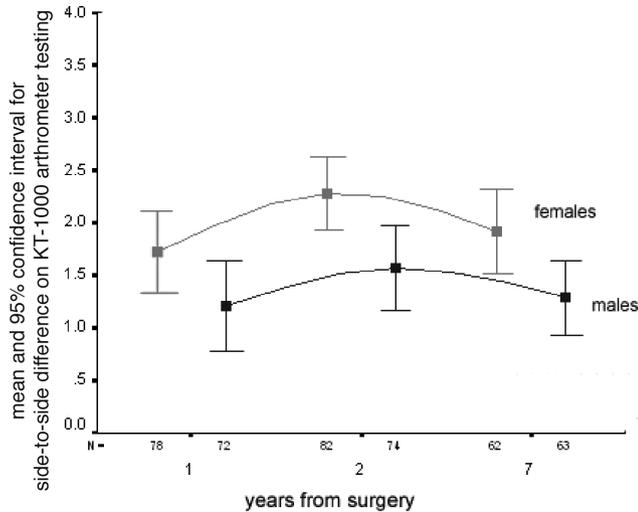


Figure 3. Side-to-side difference on manual maximum testing with the KT-1000 arthrometer. Female patients had a significantly higher KT-1000 arthrometer side-to-side difference at 1 ($P = .03$), 2 ($P = .04$), and 7 years ($P = .02$).

At 7 years, there were 2 female patients with a manual maximum test result of 5 mm. Both patients also had a grade 1 pivot-shift test finding and grade 1 Lachman test finding with firm end point and reported that they were able to participate in moderate to strenuous activities without giving way.

Regression Analysis of Laxity. Logistic regression analysis was performed to assess the relative contribution of the variables of graft size, index side, and gender on the outcome of the laxity tests. The results are shown in Table 3. The best predictor of laxity outcomes was female gender. Graft size and index side were poor predictors of laxity.

Self-Reported Data

Self-reported assessment included the IKDC categories of perceived knee function, symptoms with activity, current activity level, and the Lysholm knee score.

Perceived Knee Function. At 7 years, 97% of women (68/70) and 98% of men (72/73) with intact ACL grafts regarded their knee function as normal or nearly normal ($P = .61$). There was no significant difference between men and women for self-reported knee function at any time point.

Symptoms With Activity. Patients were asked to report the presence of pain, swelling, and giving way with various levels of activity. At the 7-year review, participation in moderate to strenuous activities was reported as possible in 91% of women (64/70) and 90% of men (66/73) without pain, 94% of women (66/70) and 97% men (71/73) without swelling, and 97% of women (68/70) and 99% of men (72/73) without any giving way. There were no significant gender differences at any time point.

Lysholm Knee Score. Seven years after surgery, the median Lysholm knee score for both men and women was 95. There was no significant difference between men and women for

the percentage of patients with a good to excellent Lysholm knee score (83) at any time point (Figure 4).

Activity Level. Before initial ACL injury, 96% of female patients and 98% of male patients reported participation in moderate to strenuous activities ($P = .23$). The percentage of patients participating in level 1 or 2 activities at each time point is shown in Figure 5. There was no significant difference between men and women in activity level at 1, 2, or 7 years.

Functional Testing

Single-Legged Hop Test. In the single-legged hop test of knee function, the patient is asked to perform a one-legged hop for distance on the injured and normal sides. Three trials for each leg are recorded and averaged. A ratio of the injured to normal knee is calculated. 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 1 year, 80% of women and 92% of men achieved a grade A hop ($P = .07$). At 2 years, 89% of women and 97% of men achieved a grade A hop ($P = .07$). At 7 years, these figures were 74% and 85%, respectively ($P = .30$). Performance on the hop test significantly decreased between 2 and 7 years for both men ($P = .01$) and women ($P = .03$).

Kneeling Pain. There was a significant increase in the percentage of patients reporting kneeling pain between 2 and 7 years in both women ($P = .004$) and men ($P = .02$). Kneeling pain was reported by 8% of women at 1 year, 4% at 2 years, and 21% at 7 years. Kneeling pain was reported by 5% of men at 1 year, 4% at 2 years, and 23% at 7 years. There was no significant difference between men and women at any time point.

Range of Motion

At 2 years, significantly more male than female patients had loss of extension ($P = .03$). No significant difference was found between men and women 7 years after surgery ($P = .13$) (see Figure 6). There was no significant gender differences in the mean extension range at 1 ($P = .74$), 2 ($P = .76$), or 7 years ($P = .65$).

There was no significant difference between men and women in flexion range of motion at any time point. One male patient lacked 7° of flexion, and all remaining patients had less than 5° flexion deficit.

Radiologic Assessment

Radiologic examination was performed on all patients preoperatively, on 74 patients (38 women and 36 men) at 2 years, and on 103 patients (49 women and 54 men) at 7 years. There was no significant difference between men and women in the percentage of patients with a normal radiologic examination result at any time point (Figure 7). Preoperatively and at 2 years, no patient had an abnormal radiologic examination result. At 7 years, 12 men (22%) and 4 women (8%) were graded B, and 1 woman (2%) was graded C ($P = .09$).

TABLE 3
Results of Regression Analysis: The Relationship Between Laxity and Gender, Side, and Graft Size

	Female Gender			Right Side			Graft Size > 7 mm		
	Adjusted Odds Ratio	95% Confidence Interval	P	Adjusted Odds Ratio	95% Confidence Interval	P	Adjusted Odds Ratio	95% Confidence Interval	P
Lachman grade 0	2.3	1.0-5.3	.05	1.1	0.5-2.4	.80	0.9	0.3-2.7	.84
Pivot-shift grade 0	2.5	0.9-7.3	.09	0.9	0.4-2.5	.91	0.6	0.1-2.9	.53
KT-1000 arthrometer < 3 mm	1.6	0.7-3.8	.25	0.83	0.4-1.9	.65	0.40	0.1-1.5	.18

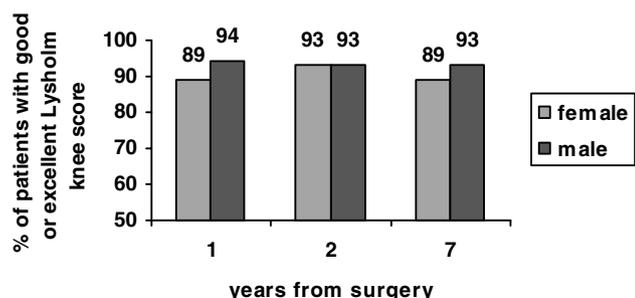


Figure 4. Percentage of patients with a good to excellent Lysholm knee score. There was no significant difference between male and female patients for any time point.

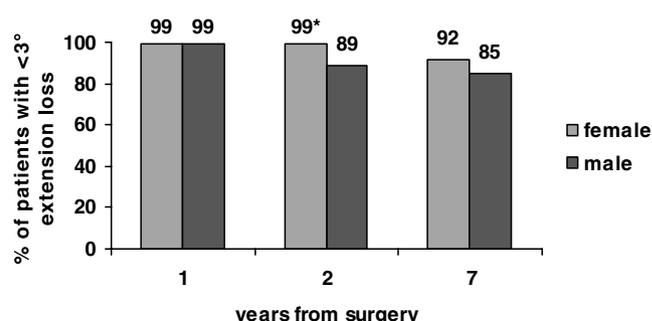


Figure 6. Percentage of patients with extension loss less than 3°. There was a significant difference at 2 years ($P = .03$). There was no significant difference at 1 year ($P = .99$) or 7 years ($P = .13$). *Denotes significant difference.

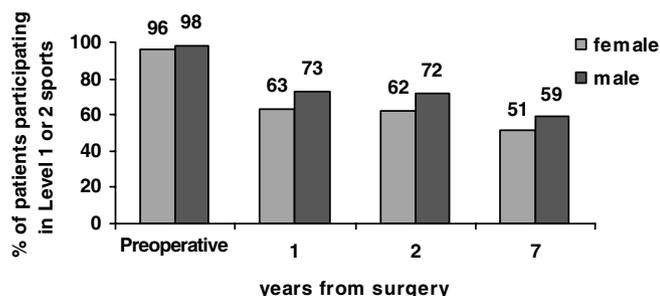


Figure 5. Percentage of patients participating in level 1 or 2 activities after surgery. There was no significant difference at any time point.

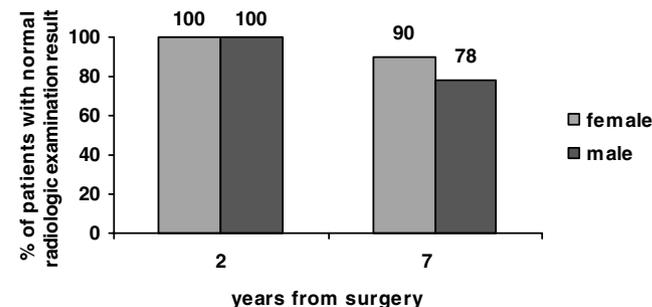


Figure 7. Percentage of patients with a normal radiologic examination result. There was no significant difference between male and female patients at 2 or 7 years ($P = .09$; $n = 74$ at 2 years and $n = 103$ at 7 years).

When men and women were grouped together, there was a significant decrease in the percentage of patients with a normal radiologic examination result between 2 and 7 years ($P = .05$). This deterioration may have been slightly greater in the men ($P = .08$) than in women ($P = .32$), but this finding was not statistically significant when the male and female patients were separated.

Regression analysis was performed to assess the relative contribution of the variables of gender, age, extension loss at 2 years, activity level at 2 years, and Lachman test result at 2 years on the outcome of the radiologic assessment. Those with an extension loss of greater than or equal to 3° at 2 years had 10 times greater odds of having an

abnormal radiologic assessment at 7 years (odds ratio, 10.2; 95% confidence interval, 1.5-70.8; $P = .02$). The variables of age, gender, Lachman test, and activity level at 2 years were not significant predictors of radiologic assessment at 7 years. Radiologic assessment was not strongly correlated with self-reported knee function ($r = 0.25$) or Lysholm knee score ($r = 0.21$).

Overall IKDC Grade

The worst grade from each category of the IKDC determines the overall grade. There was no significant difference between men and women in overall IKDC grade for

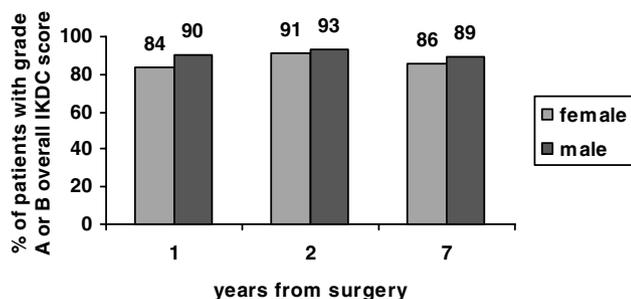


Figure 8. Percentage of patients with a grade A or B overall International Knee Documentation Committee (IKDC) score. There was no significant gender difference at any time point.

any time point. There was no significant change between 2 and 7 years in either group. Figure 8 shows the percentage of patients with an overall IKDC grade A or B.

DISCUSSION

In this study, we compared the outcomes in men and women after isolated ACL reconstruction with hamstring tendon autograft and interference screw fixation. We found that women had significantly greater clinical laxity than did men at 7 years, but the magnitude of this difference was small. No significant gender differences were found for graft rupture, activity level, or self-reported or functional assessments. Importantly, the presence of greater laxity had no effect on activity level and subjective or functional assessments.

Women had significantly greater laxity than did men on Lachman, pivot-shift, and mean manual maximum testing at all time points (Figures 1-3), but the magnitude of the difference was small. Overall, the laxity results for both male and female patients were excellent, which may be related to the fact that no patient in this study had significant meniscal resection, which increases laxity.¹⁸ Others have reported greater laxity in women compared with men when using hamstring tendon graft.^{8,15,24} Noojin et al²⁴ reported significantly greater laxity in women than in men as demonstrated by KT-1000 arthrometer differences, as well as Lachman and pivot-shift tests. As was the case in our study, the magnitude of the laxity difference between men and women on instrumented manual maximum testing was small: 0.63 mm. Gobbi et al¹⁵ have also reported significantly greater laxity in female athletes who had an ACL reconstruction with the hamstring tendon graft and EndoButton fixation by a magnitude of 0.6 mm on OSICA4000 testing. Corry et al⁸ compared 82 patellar tendon reconstructions with 85 hamstring tendon reconstructions 2 years after ACL reconstructions, finding greater laxity on instrumented testing in women with hamstring tendon reconstruction than in men with hamstring tendon or in men or women with patellar tendon reconstruction. The magnitude of the difference between the men and women in this study was 1.4 mm on instrumented testing with 89 N of force; the manual maximum results were not reported. The same group of patients was subsequently assessed by Pinczewski et al,²⁷ and the difference in laxity between the men and women at 2 years had normalized

by 5 years. However, the aim of the Pinczewski et al study was to compare the outcome of hamstring and patellar tendon grafts; therefore, it may not have been adequately powered for detecting gender differences. Overall, our findings of greater laxity in women are comparable with those reported by other authors when using the hamstring tendon graft, irrespective of fixation methods.

The reason for the greater laxity in women compared with men is unclear. Some authors have attributed this greater laxity to the smaller hamstring tendon graft size in women.^{15,24} Although in our study the mean hamstring graft diameter was significantly smaller in women than in men (mean, 6.6 mm for women and 7.0 mm for men; $P < .01$), no correlation between graft size and manual maximum testing at 7 years was found ($r = -0.17$), and regression analysis did not find graft size to be a predictor of laxity. Therefore, we favor an alternative hypothesis⁸ that the observed laxity in women is directly related to lower bone mineral density. Although bone mineral density was not measured in this study, it has been shown by others that women have lower bone mineral densities than do men.²⁰ There is also recent evidence that bone mineral density decreases further in female patients after ACL reconstruction and persists for 1 year after surgery.⁹ Furthermore, Brand et al⁷ have shown that bone mineral density is related to graft strength in cadaveric studies. Perhaps the lower bone mineral density of the female patients adversely affects their initial fixation, making them more susceptible to graft creep with cyclic loading, which results in greater laxity. This hypothesis is supported by a recent randomized controlled trial of women that found a supplementary tibial staple in addition to interference screw fixation improved the postoperative laxity assessments.¹⁷ Regardless of the cause of greater laxity in women undergoing ACL reconstruction, there is no evidence that laxity has a significant effect on self-reported or functional outcomes.

We did not find a difference in functional outcomes between men and women when function was measured by the Lysholm knee score, self-reported knee function, activity level, or performance of the hop test at 7 years. Despite slightly greater increases in laxity measurements seen in female patients with hamstring tendon graft, the overall self-reported assessments remain excellent in women, with more than 97% reporting normal or nearly normal knee function and more than 89% with good to excellent Lysholm knee scores. Therefore, higher laxity measurements do not appear to influence the self-reported or functional outcome assessments. Indeed, recently, others have shown that instrumented laxity and Lachman tests were poor predictors of subjective and functional outcome after ACL reconstruction.^{19,23} As the difference in mean laxity between genders found in our study was small, and there was no significant gender difference in failure rates, the clinical relevance of the greater laxity remains unclear. Hill et al¹⁷ have shown laxity in female patients may be reduced with the use of supplementary tibial fixation, but this reduction is associated with increased kneeling pain, and therefore Hill et al did not recommend its continued use. Others have shown no difference between men and women on laxity testing when a patellar tendon graft is used for ACL reconstruction.^{5,8,12} Therefore, it

could be argued that the patellar tendon is a more appropriate graft to use for women. However, reconstruction with the patellar tendon graft may be associated with poorer cosmesis, higher graft morbidity, patellofemoral problems, and a more difficult rehabilitation.^{4,6,10,11,13,27,28} There is also evidence that use of the patellar tendon graft may be associated with greater osteoarthritis compared with the hamstring graft at 5 years.²⁷ The high incidence of excellent self-reported and functional assessments seen in this study supports the continued use of the hamstring tendon graft and interference screw fixation in both men and women.

Inevitably, the techniques and tools used to reconstruct the ACL evolve. At the time of this study, there was only one size of interference screw (7 × 25 mm) available for fixation. The diameter of the tunnel was determined by the size of the graft, and the same size screw was used for all patients. The influence of these factors is unknown. Now, the surgeon is able to select from a larger range of screw sizes in both diameter and length. It is the current practice of our surgeons to oversize the screw in relation to the tunnel and the graft in female patients and/or those with clinical evidence of lower bone mineral density. This factor may, in part, improve the postoperative laxity in female patients, but further study in this area is required.

We found no significant difference between men and women in the rate of ACL graft rupture. Ten of 100 female patients (10%) and 11 of 100 male patients (11%) suffered a graft rupture within 7 years. If the 2 additional women with a manual maximum test result of 6 mm, both with grade 1 Lachman and pivot-shift test finding were included as failures, there would still be no difference between genders. Others have reported no significant differences in failure rates between men and women after ACL reconstruction with patellar tendon grafts^{5,12} or hamstring tendon grafts.¹⁵ However, Noojin et al²⁴ reported a clinical failure rate of 23% in women and 4% in men after ACL reconstruction with hamstring tendon autograft. However, they included any patient with a grade 1+ (glide) pivot-shift test result as a failure and conceded that this finding increased the failure rate for female patients. If failure were defined as greater than 5-mm side-to-side difference on instrumented testing and Lachman or pivot-shift result of 2 or greater, then the adjusted failure rate in the Noojin et al²⁴ study would be 10% in the female patients, comparable with our study.

In addition to the 21 patients who suffered a graft rupture during the study period, there were 4 women (4%) and 8 men (8%) who suffered a contralateral ACL injury, including 1 male patient who suffered both an ACL graft rupture and a contralateral ACL injury. Thus, after ACL reconstruction, a total of 14 of 100 women and 19 of 100 men had a repeat ACL injury over the 7-year follow-up period ($P = .33$). The annual incidence of ACL injuries in the normal healthy population is reported to be between 1.5% and 1.7% per year.^{21,30} Although no significant difference between men and women was found, the incidence of repeat ACL injury in men may be slightly higher than in women and in the normal active population.

In both men and women, there was a significant increase in the incidence of kneeling pain between 2 and 7 years to 21% of women and 23% of men. Others have shown that

kneeling pain is more commonly associated with use of the patellar tendon graft than with the hamstring tendon graft.^{4,13,27} Indeed, lower graft morbidity is thought to be an advantage of the hamstring tendon graft. Incidences of kneeling pain or patellofemoral knee pain approximating 20% with the hamstring graft have been reported by others,^{27,28} and in these studies, significantly higher incidences approximating 40% were found with the patellar tendon graft. The reason for the increase in symptomatic kneeling pain is unclear, and further studies may need to examine if this increase approximates the incidence seen with the patellar tendon graft over the long term.

Early signs of degeneration on radiologic assessment at 7 years were present in 5 of the 49 women (10%) and 12 of the 54 men (22%) who had radiologic assessment ($P = .09$). Regression analysis revealed that those with an extension loss of greater than or equal to 3° at 2 years had 10 times greater odds of having an abnormal radiologic assessment at 7 years (odds ratio, 9.8; 95% confidence interval, 1.5-65.9; $P = .02$). However, radiologic assessment was completed in only 102 of the 143 patients seen at 7 years; therefore, these findings should be interpreted with caution. This potential early warning sign may warrant counseling of patients exhibiting early extension loss about the increased risk of degeneration, the value of avoiding high-impact activities, and the importance of weight minimization.

In this study, ACL reconstruction using hamstring tendon autograft afforded excellent self-reported and objective results in both men and women after 7 years. Significantly greater laxity on physical examination was present in female patients when compared with male patients, but the magnitude of this difference was small and had no effect on graft failure, activity level, and subjective or functional assessment. On the basis of this study, and in view of the greater morbidity associated with the patellar tendon graft, we believe that the hamstring tendon graft remains an acceptable graft material in both men and women for ACL reconstruction.

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