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S Thompson

L Salmon

A Waller

J Linklater

J Roe

See next page for additional authors

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Authors
S Thompson, L Salmon, A Waller, J Linklater, J Roe, and L Pinczewski

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Twenty-Year Outcome of a Longitudinal Prospective Evaluation of Isolated Endoscopic Anterior Cruciate Ligament Reconstruction with Either Patellar Tendon or Hamstring Autograft

ABSTRACT

Background: Long-term prospective studies of isolated endoscopic anterior cruciate ligament (ACL) reconstruction are limited and may include confounding factors.

Purpose: This study compares the outcomes of isolated ACL reconstruction using patellar tendon autograft (PT) and hamstring autograft (HT) in 180 patients over 20 years.

Study Design: Case series; Level of evidence, 4.

Methods: 180 participants undergoing isolated ACL reconstruction between 1993 and 1994 were prospectively recruited. Evaluation was performed at 1, 2, 5, 7, 10, 15, and 20 years after surgery and included the International Knee Documentation Committee (IKDC) Knee ligament evaluation with radiographic evaluation, KT1000, and subjective scores.

Results: Over 20 years, 16 (18%) had an ACL graft rupture in the HT group, and 9 (10%) in the PT group (p=0.13). ACL graft rupture was associated with male gender (OR 3.9, p=0.007), non-ideal tunnel position (OR 3.6, p=0.019) and those aged <18 at time of surgery (OR 4.6, p=0.003). The odds of contralateral ACL rupture, were increased in those with the PT graft compared to the HT graft (OR 2.2, p=0.02) , and those age <18 at the time of surgery (OR 3.4, p=0.001). The mean IKDC score was 86 for the PT and 89 for HT at 20 years (p=0.18). At 20 years 53% of the PT group and 57% of the HT group participated in strenuous or very strenuous activities (p=0.55). Kneeling pain was present in 20% of the HT group and 63% of PT group (p=0.018). Radiographic osteoarthritic change was found in 61% of the PT group, and 41% of the HT group (p=0.008) at 20 years.

Conclusion: Participants receiving the PT graft had significantly worse outcomes compared to those receiving HT graft regarding radiologically detectable osteoarthritis, kneeling pain and contralateral ACL injury. At 20 years both HT and PT autografts continue to provide good subjective outcomes and objective stability. However, further ACL injury is common, particularly in males, the young, and those with tunnel malposition.

Keywords: knee; anterior cruciate ligament (ACL); reconstruction; long-term outcome

Clinical Relevance: There is limited literature reporting the long-term outcome of ACL reconstructive surgery, specifically regarding reinjury, arthritis and functional outcome. This study reports the outcomes of ACL reconstruction over 20 years, providing better understanding of the long term effects of ACL reconstruction and the incidence of further ACL injury.

What is known about the subject: There is a paucity of long-term outcomes of single incision, endoscopic reconstruction of the ACL. This prospective study excludes confounding factors and reports the 20 year results of isolated ACL rupture treated with either autologous quadruple strand hamstring or patellar tendon autograft.

What this study adds to existing knowledge: We report the long term outcome of both the reconstructed knee and the natural history of further injury to the contralateral ACL. This is the longest prospective follow up study of endoscopic ACL reconstruction in the literature.

INTRODUCTION

Anterior cruciate ligament (ACL) injury commonly occurs in the young active population, and may lead to recurrent episodic instability, pain, meniscal injuries, osteoarthritis (OA), affect long-term function of the knee and subsequent degenerative change.[5, 6, 10, 11, 20, 29, 31, 42] Endoscopic reconstruction is considered the gold standard for the treatment of ACL ruptures, aiming to produce a stable knee by recreating the ACL anatomy.[9, 14, 20, 22, 28] There is a paucity of studies confirming the long term results of ACL reconstruction, and it may well be that timely reconstruction may prevent osteoarthritis (OA).[13, 16, 20, 30, 47]

Few studies have reported the long-term outcomes of single-incision endoscopic reconstruction of the ACL without associated other injuries including meniscal, collateral ligament, and chondral surface damage.[6, 21, 28, 38, 41] This prospective study excludes these confounding factors and has been previously reported in the literature at 2, 5, 7, 10 and 15 years after surgery.[12, 24, 34, 35, 37] The purpose of this study was to report the 20-year outcomes of isolated ACL ruptures treated with endoscopic reconstruction using middle-third patellar tendon or quadrupled hamstring autografts. Our hypothesis was that the long term outcome of ACL reconstruction is affected by graft selection.

MATERIALS AND METHODS

Ethical approval was obtained from an independent hospital Human Ethics Committee [redacted] This study is an ongoing prospective cohort study with the twenty year results being reported.

Patient Selection

ACL reconstruction was offered to patients who demonstrated clinical ACL instability with at least grade II Lachman and Pivot Shift tests. The acute injury was managed with physical therapy to facilitate a full or near full range of movement with minimal pain and swelling prior to surgery. At the time of surgery those requiring removal of more than one third of one meniscus were excluded from the study. There were 17 cases included in the study that had meniscal suturing. The process of patient selection for this study has been previously documented and the inclusion and exclusion criteria are presented in Table 1. The large number of exclusions is due to the strict criteria, which were designed to minimize the confounding variables and allow a true comparison of results between graft types.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Endoscopic ACL Reconstruction with either patellar tendon 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 Abnormal contralateral knee joint Patients seeking compensation for their injury Patients unwilling to participate in a research programme

From January 1993 to April 1994, 333 patients were prospectively examined and underwent surgical reconstruction of the ACL using PT autograft. Of this group, 90 patients fulfilled the study inclusion criteria and were included in this study. In October 1993, the senior author [redacted] started using the HT autograft, and after April 1994 used the HT graft exclusively. There were 39 patients who underwent surgery during the 6 month overlap period, 15 received the HT autograft and 24 received the PT autograft. The decision of which graft to use during this period was based on the initial consultation where patients who were seen from mid October 1993 were offered the HT autograft. From October 1993 to November 1994, 372 patients underwent ACL reconstruction using 4 strand HT autograft. Out of this group, 90 met the selection criteria and were included in this study.

Surgical Technique

All procedures were performed by the senior author [redacted]). The technique was standardized for all patients and has previously been described in detail.[12, 49] In the PT group, the ipsilateral middle third bone - patellar tendon - bone graft was used, and the tunnel diameter was 1mm greater than the measured bone block diameter (range 8 to 11mm). In the HT group, a 4 strand Gracilis and Semitendinosus tendon graft was used, and the tunnel diameter equaled the measured diameter of the graft (range 6 to 9mm).

The femoral tunnel was drilled before the tibial tunnel via the anteromedial arthroscopic portal with the knee in maximal flexion, and positioned 5mm anterior to the posterior capsular insertion.

The tibial tunnel was centered on a line between the anterior tibial spine and the posterior margin of the anterior horn of the lateral meniscus, half a graft diameter lateral along that line.

In all cases the fixation consisted of a 7 x 25mm titanium cannulated interference screw (RCI, Smith and Nephew Endoscopy, Andover, Mass) for both femoral and tibial fixation.

Rehabilitation

Both groups were treated with the same rehabilitation program. Patients began weight bearing and co-contractions of the hamstrings and quadriceps immediately after surgery. No brace was used and crutches were discarded as soon as possible. An accelerated rehabilitation program was instituted by physiotherapists, focusing on achieving full extension ideally by 14 days after surgery, and full flexion and extension by 6 weeks. Jogging was commenced at 6 weeks, and return to competitive sport was restricted until 6 months and only after reconfirming knee stability on clinical examination.

Assessment

All patients were assessed by an experienced independent examiner prior to surgery and 6 and 12 months after surgery, then annually for 5 years and again at 7, 10, 15, and 20 years after surgery. The International Knee Documentation Committee (IKDC) evaluation form was used and symptoms and signs of knee function were assessed to determine the IKDC grade. From 2003 onwards the updated IKDC (2000) evaluation form was used.[3, 7] The Lysholm knee score was obtained by a self-administered questionnaire[18, 26, 46]. Clinical assessment of knee stability was performed and recorded as a side–to-side difference compared to the normal contralateral knee, using the Lachman, Anterior Drawer and the Pivot Shift tests. Lachman test was graded as follows: Grade 0 is no difference, grade 1 is 1 to 5mm laxity, grade 2 is 5 to 10mm laxity, and grade 3 is greater than 10mm laxity. The Pivot Shift test was assessed as grade 0 being negative, grade 1 being a glide, grade 2 a clunk, and grade 3 being gross. Instrumented laxity testing was determined using the KT-1000 arthrometer (MEDmetric Corp, San Diego, Calif) measuring side-to-side differences in displacement on manual maximum testing[25]. Range of motion was determined using a goniometer. Single leg hop test was also performed as a further assessment of function.

Radiographs were taken at 2, 5, 7, 10, 15 and 20 years after surgery including weight bearing anteroposterior (AP), 30 degree flexion posteroanterior (PA), lateral and 45 degree Merchant

121 views. These were assessed by an independent experienced musculoskeletal radiologist for
122 evidence of degenerative change in the medial, lateral and patellofemoral compartments and
123 classified according to the IKDC guidelines as being: A, normal; B, minimal change and barely
124 detectable joint space narrowing; C, moderate changes and joint space narrowing of up to 50%;
125 and D, severe changes and more than 50% joint space narrowing. The worst grade of the three
126 compartments was used to assign the overall radiographic grade.

127 The radiographs were also reviewed to assess tunnel position, using methods previously
128 reported.[36] Ideal tunnel position was defined as being sagittal tibial tunnel 40-50% anterior,
129 sagittal femoral tunnel 80-90% posterior, and coronal graft inclination greater than 17 degrees as
130 supported by previous study[36].

131 Statistical Method

132 The outcomes were compared between groups were assessed using the Mann-Whitney U test for
133 continuous measurements (mean KT-1000 arthrometer, Lysholm score) and the chi-sqaured test
134 ($\chi 2$) test for ordered categorical variables (IKDC categories, Lachman, Pivot Shift test). The
135 Wilcoxon signed ranked test was used to assess change over time. Logistic regression analysis was
136 used to assess the relative contribution of selected variables on dichotomous outcomes. SPSS 11.0
137 for Windows (SPSS Science Inc., Chicago, Il) was used for all the above statistical analysis. Logistic
138 regression was used for the relationship between radiologic outcomes and the variables of further
139 surgery and tunnel placement. Survivorship of the ACL graft and contralateral ACL was calculated
140 using the Kaplan-Meier survival method. Comparisons of survival curves were made with log-rank
141 tests and univariate Cox Regression. Factors that were significant ($p<0.05$) on univariate survival
142 analysis were entered into multivariate Cox regression and then eliminated in a step-wise fashion,
143 until only the independent significant factors remained. Statistical significance was set at a 5%
144 level.

RESULTS

Follow Up

The original study group contained 180 patients, with 90 patients in each group. The participant flow at 20 years is shown in Figure 1.

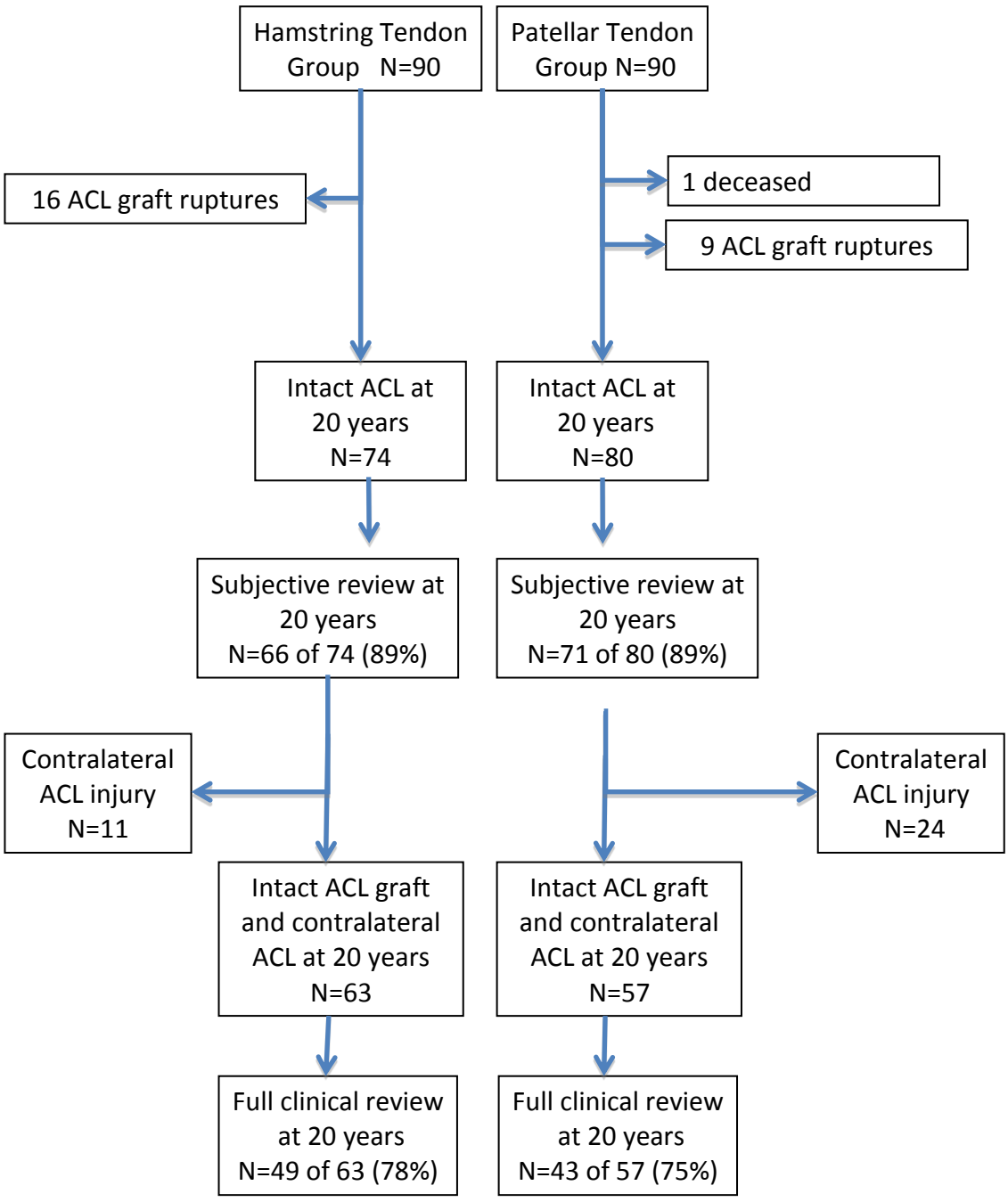


Figure 1: Participant flow at 20 years

The rate of follow up for the 2 to 20 years reviews is shown in Table 2.

Table 2: Patients reviewed with subjective results (Graft Ruptures and Deaths Excluded)

Follow-up years	Hamstring Tendon Group	Patellar Tendon Group
2	78 of 85 (92%)	79 of 87 (91%)
5	76 of 83 (92%)	79 of 87 (91%)
7	73 of 82 (89%)	77 of 85 (91%)
10	74 of 78 (95%)	75 of 82 (91%)
15	70 of 75 (93%)	72 of 82 (88%)
20	66 of 74 (89%)	71 of 80 (89%)

The objective components of the IKDC require comparison of the reconstructed knee to the contralateral normal knee, however 40 patients sustained a contralateral ACL rupture within the follow up period of this study. The objective results for these patients have therefore been removed, while the subjective results have been included.

Demographics

At surgery, the mean age of the PT group was 25 years (range 15-42) and the mean age of the HT group was 24 years (range 13-52). 14 patients from the PT group and 15 patients from the HT group were aged 18 or less at the time of surgery. There were 48 males in the PT group and 47 males in the HT group.

Operative Findings

Reconstruction was performed less than 12 weeks after injury for 70 out of 90 in the HT group, and 66 out of 90 in the PT group (p=0.42). Medial meniscal injuries were noted in 20 out of 90 in the HT group, and 18 out of 90 in the PT group. Lateral meniscal injuries were seen in 43 out of 90 in the HT group, and 34 out of 90 in the PT group (p=0.35). Meniscal suturing was performed in 10

HT, and 7 PT patients, and minimal resection of less than one third of the meniscus in 9 HT and 6 PT patients (p=0.52).

Further Surgery

The details of any subsequent surgery on the index knee are listed in Table 3.

Table 3: Further Surgery over 20 years.

	Patellar Tendon Group	Hamstring Tendon Group
No further surgery to index knee*	71	63
Meniscectomy*	9	12
Revision ACL reconstruction	6	14
Excision of tibial screw	1	2
Excision patellar tendon cyst	1	
Excision Cyclops	2	1
Arthroscopy	2	
Open reduction and internal fixation of tibial fracture		1
Femoral Varising osteotomy		1

*No significant difference between PT and HT group for incidence of further surgery (p=0.15), or meniscectomy (p=0.19)

ACL Graft Rupture

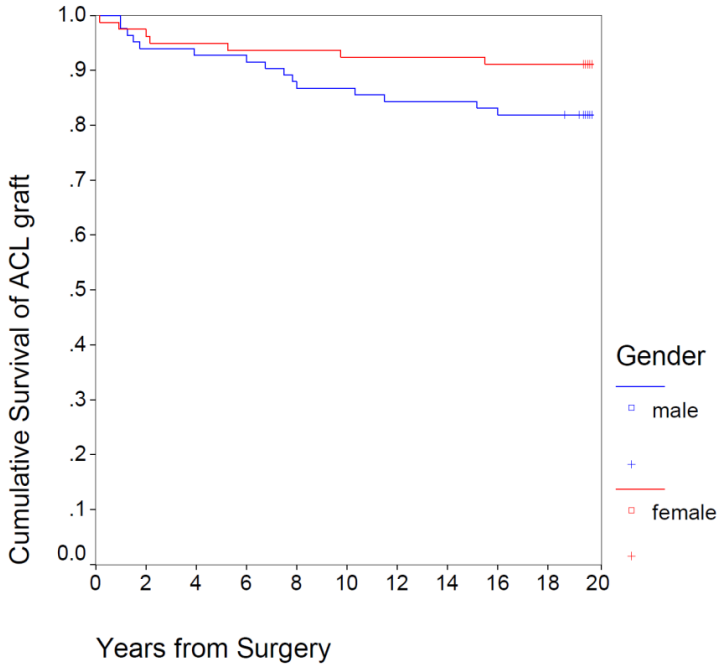
ACL graft rupture occurred in 16 patients (18%) from the HT group and 9 patients (10%) in the PT group (p=0.13).

Regression analysis was performed to assess the association between ACL graft survival and the selected variables of gender, family history of ACL injury, graft type, age 18 or less at time of surgery and radiographic tunnel position. The significant variables are shown in Table 4 and

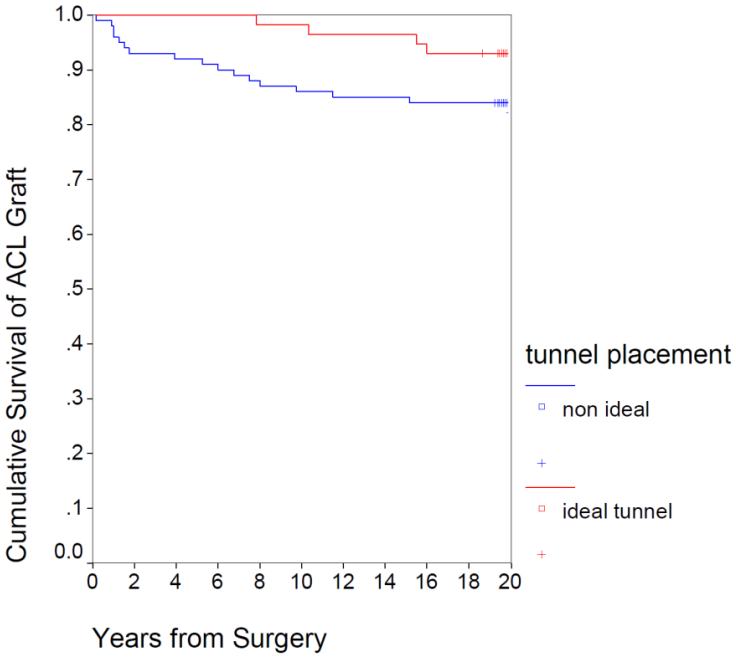
Figures 2-4. ACL graft rupture was not significantly associated with graft type (p=0.11), or family history of ACL injury (p=0.276) over 20 years.

Table 4: Survival of the ACL Graft with Hazard Ratios for Significant Variables

Factor and Category		2 Year Survival	5 Year Survival	7 Year Survival	10 Year Survival	15 Year Survival	20 Year Survival	Hazard Ratio	95% CI	p-value
All		95	94	92	90	88	85			
Gender	Males	94	93	90	87	83	78	3.9	1.5- 10.6	0.007
	Females	96	95	94	92	91	89			
Age	18 or less	85	81	76	76	71	67	4.6	1.7-12.7	0.003
	>18 years	96	96	94	91	89	88			
Tunnel	Ideal	100	100	100	96	95	93	3.6	1.2-10.3	0.02
placement	Non-ideal	93	92	89	86	85	82			



Figures 2: Cumulative survival of ACL Graft according to Gender. Males were more likely to rupture ACL graft than females with an odds ratio of 3.9 (95% CI 1.5 – 10.6, p=0.007).

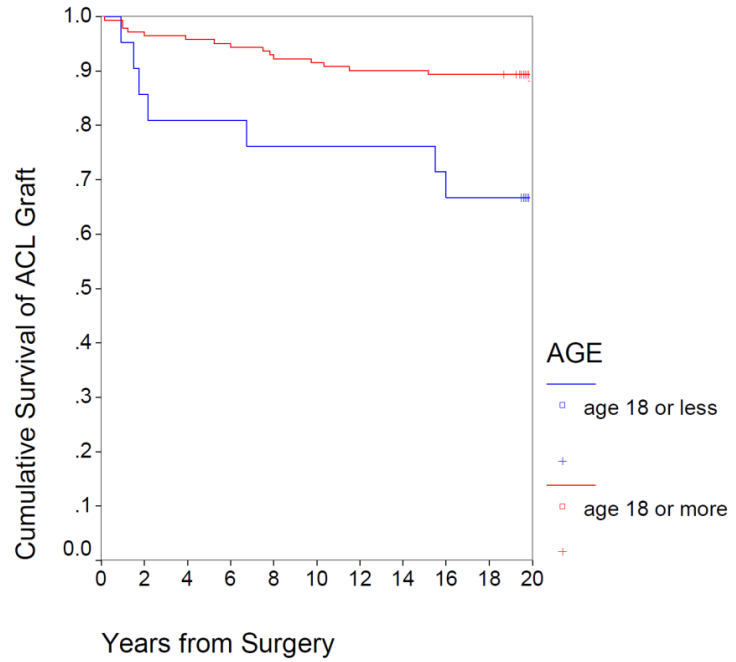


188

189 **Figures 3: Cumulative survival of ACL Graft according to Tunnel placement.** Non-ideal tunnel

190 position was associated with ACL graft rupture compared to ideal tunnel position with an odds

191 ratio of 3.6 (95% CI 1.2 – 10.3, p=0.019).



192

193 **Figures 4: Cumulative survival of ACL Graft according to Age.** Those 18 or less had 4.6 times

194 greater odds of an ACL graft rupture (95%CI 1.7-12.7, p=0.003), compared to those over 18 years

195 at the time of ACL reconstruction.

196

197 Contralateral ACL Rupture

198 Over 20 years 40 participants sustained a rupture of the contralateral ACL, 27 subjects (30%) who

199 received the PT graft and 13 subjects (14%) who received the HT graft (p=0.035).

200 Regression analysis was performed to assess the association between CACL survival and the

201 selected variables of gender, family history of ACL injury, graft type, and age 18 or less at time of

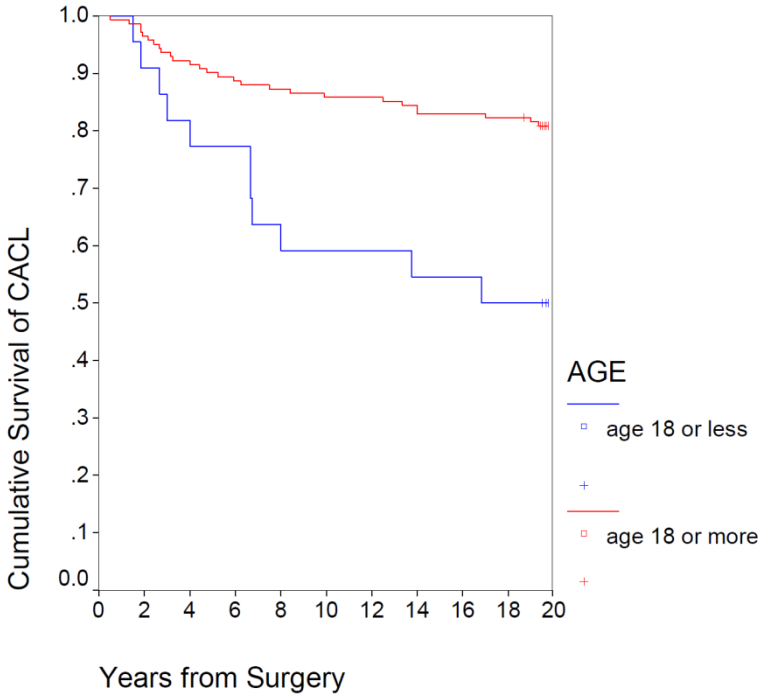
202 surgery. The significant variables are shown in Table 5 and Figures 5-6. CACL survival was not

203 significantly associated with gender (p=0.24), or family history of ACL injury (p=0.47) over 20 years.

204

205 **Table 5: Survival of the Contralateral ACL with Hazard Ratios for Significant Variables**

Factor and Category		2 Year Survival	5 Year Survival	7 Year Survival	10 Year Survival	15 Year Survival	20 Year Survival	Hazard Ratio	95% CI	p-value
All		96	88	85	82	79	75			
Age	18 or less	91	77	64	59	55	50	3.4	1.7-6.8	0.001
	>18 years	96	70	88	86	83	81			
Graft	Patellar	98	87	80	76	72	70	2.2	1.2-4.3	0.022
	Hamstring	94	90	89	89	85	84			



206

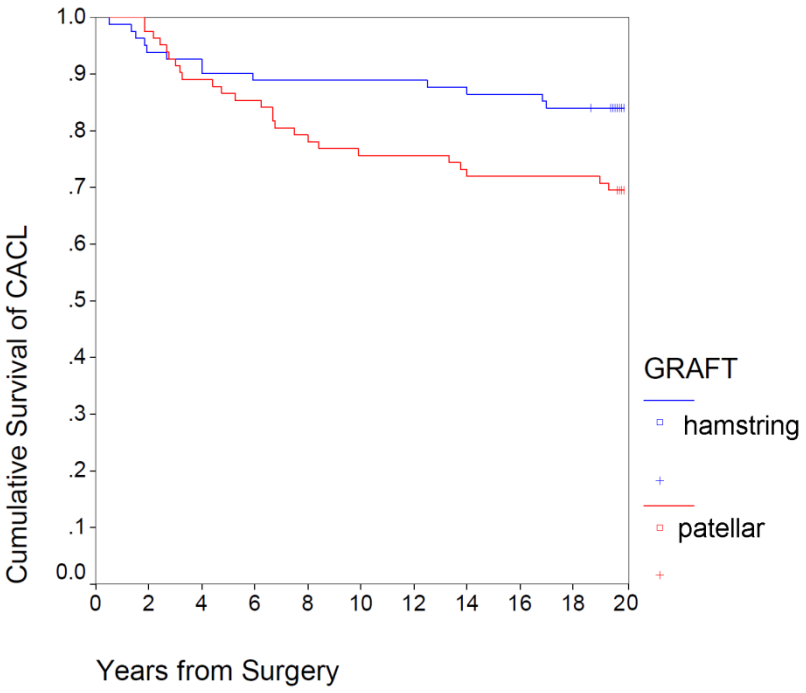
207 **Figures 5: Cumulative survival of Contralateral ACL according to age.** Those aged 18 or less had

208 3.4 time greater odds of a CACL rupture (95% CI 1.7-6.8, p=0.001), compared to those over 18

209 years at the time of ACL reconstruction

210

211



Figures 6: Cumulative survival of Contralateral ACL according to Graft Type. Those who received the PT graft had 2.2 times greater odds of CACL rupture (95%CI 1.1-4.3, p=0.02), compared to those that received the HT graft.

Incidence of further ACL injury

Further ACL injury to either the reconstructed or contralateral knee occured in 30% (n=27) of the HT group, and 37% (n=33) in the PT group (p=0.343).

SUBJECTIVE RESULTS

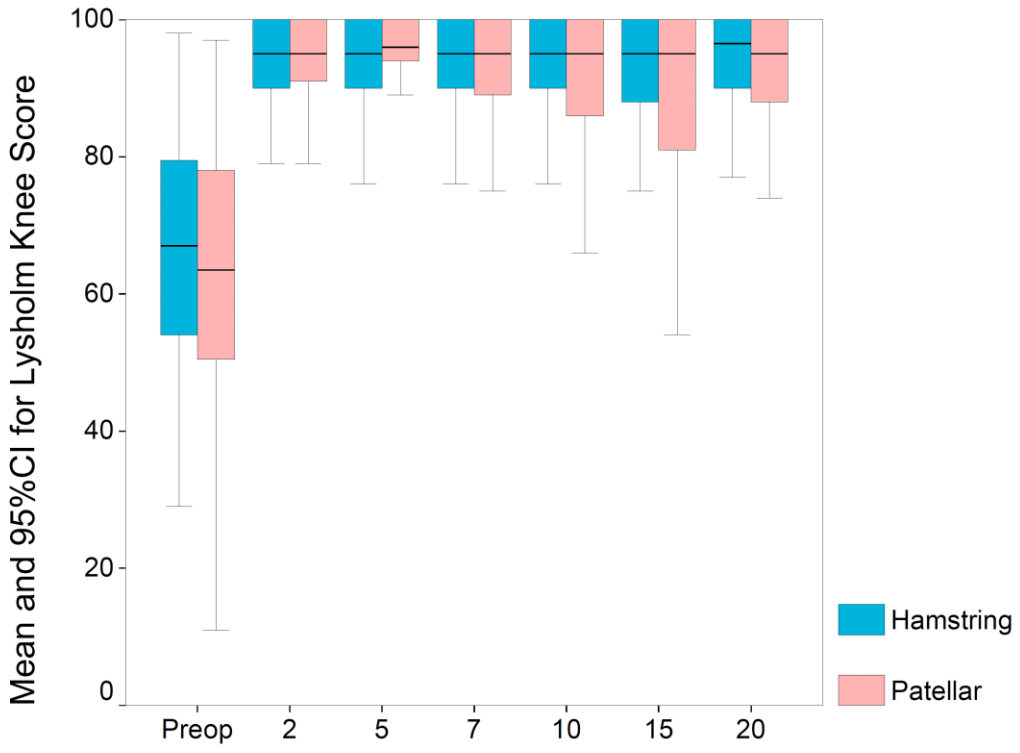
IKDC Subjective Score

The mean IKDC score for the HT group was 89 (SD=12), compared to the PT group with a mean of 86 (SD=16) (p=0.18).

Lysholm Knee Score

At the 20 years the mean Lysholm Knee Score was 92 (SD 16)in the HT group and 92 (SD 11) in the PT group (p=0.88). The results of the Lysholm Knee Score over the 20 year period is shown in Figure 7.

Figure 7: Mean and 95% Confidence Interval for Lysholm Knee Score of Hamstring and Patellar Grafts and 2 to 20 year review periods



Activity Level

Participants rated their current regular activity level as being very strenuous (such as jumping and pivoting sports like basketball or soccer), strenuous (such as heavy physical work, skiing, or tennis), moderate (such as moderate physical work or running), light (such as walking and house or yard work), or unable to perform any of the above activities. There was no significant difference in activity level between the HT group and the PT group (Table 6, p=0.55).

Table 6: Comparison of Activity Levels at 20 years between hamstring and patellar tendon groups. There was no significant difference between the groups at 20 years (p=0.55)

	Patellar Tendon Group	Hamstring Tendon Group
Very Strenuous	34%	42%
Strenuous	23%	21%
Moderate	31%	21%
Light	1%	15%
Unable	0%	0%

Kneeling Pain

Kneeling pain was reported as not difficult, minimally difficult, moderately difficult, extremely difficult or unable. No or mild difficulty with kneeling was reported by 80% (n=53) of the HT group and 62% (n=44) of the PT group (p=0.018).

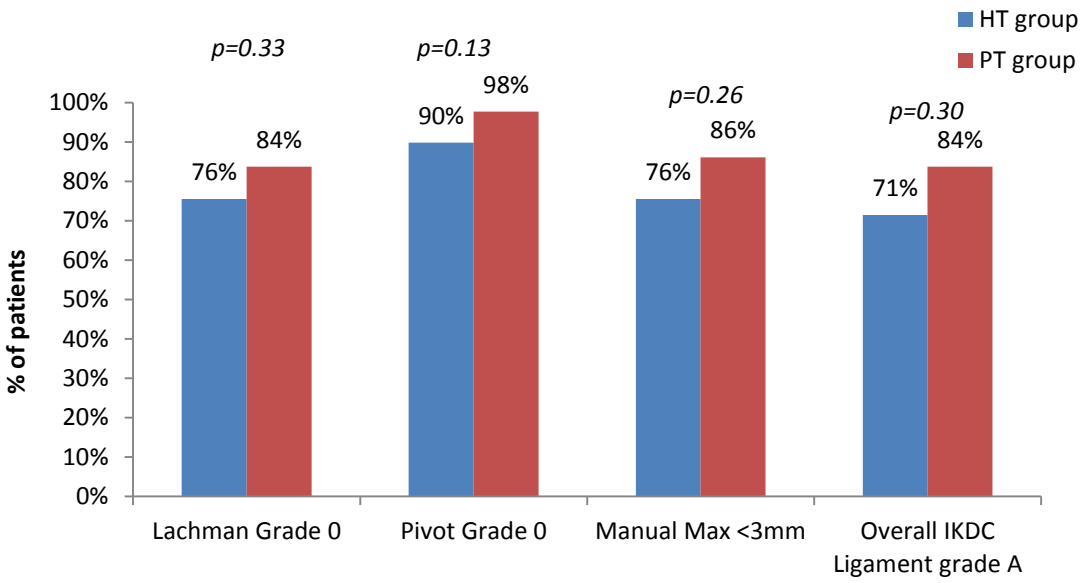
OBJECTIVE RESULTS

Objective results assessed include clinical ligament evaluation, range of movement, single leg hop test, and the overall IKDC grade. Given that these clinical assessments require comparison to the normal contralateral knee, those patients who had sustained a contralateral ACL rupture are not included in these results after their contralateral injury. As a result there were 49 of a possible 63 patients tested clinically in the HT group (78%), and 43 of a possible 58 (74%) in the PT group at 20 years.

Clinical Ligament Evaluation

Laxity was assessed with Lachman test and Pivot Shift, and instrumented testing with the KT1000 arthrometer. Figure 8 summarises the overall IKDC clinical ligament evaluation at 20 years.

Figure 8: Patients with "Normal" Ligament Examination at 20 years

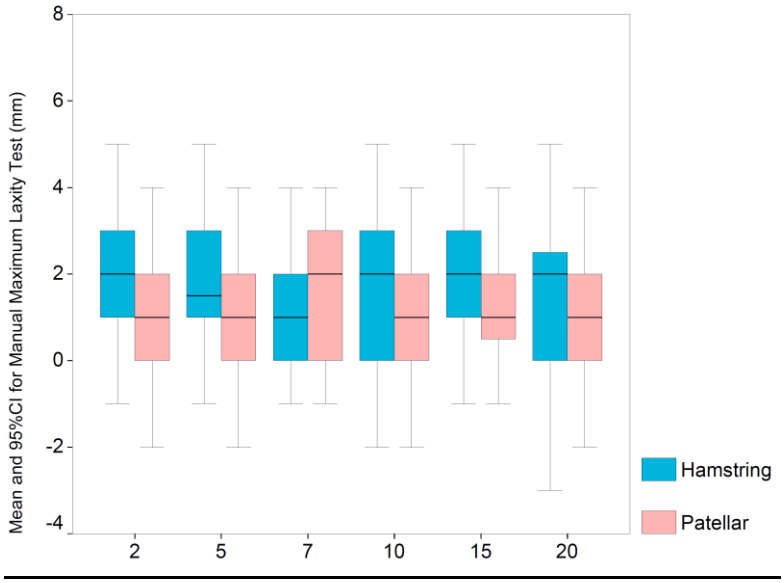


Lachman test. In the HT group 76% of patients (n=37) had grade 0 Lachman, and 25% (n=12) had grade 1. In the PT group 84% (n=36) had grade 0 and 16% (n=7) had grade 1 Lachman test (p=0.33). There were no cases in either group with grade 2 or 3 Lachman.

Pivot shift test. In the HT group 90% (n=44) had a grade 0 Pivot and 10% (n=5) had a grade 1 Pivot. In the PT group 98% (n=42) had a grade 0 Pivot and 2% (n=1) had a grade 1 Pivot (p=0.13). No patients had a grade 2 Pivot.

Instrumented testing. At 20 years, <3mm side to side difference on KT1000 manual maximum testing was found in 76% (n=37) of the HT group and 86% (n=37) of the PT group (p=0.26). The mean manual maximum displacement between 2-20 years is shown in Figure 9, at 20 years this was 1.0 (SD 1.5) in the PT group and 1.6mm (SD 1.8) in the HT group (p=0.08)

Figure 9: Mean and 95% Confidence Interval for Side to Side Difference in Instrumented Laxity Testing with KT1000 Arthrometer of Hamstring and Patellar Grafts and 2 to 20 year review periods



Range of Movement

The HT group had 94% (n=46) with less than 3 degrees and 6% (n=3) with 3 to 5 degrees extension loss. The PT group had 86% (n=37) with less than 3 degrees and 9% (n=4) with 3 to 5 degrees extension loss, and 5% (n=2) with more than 5 degrees extension loss (p=0.254). One patient from each the HT and PT group had a flexion deficit of more than 5 degrees (p=0.365)

Single Leg Hop Test

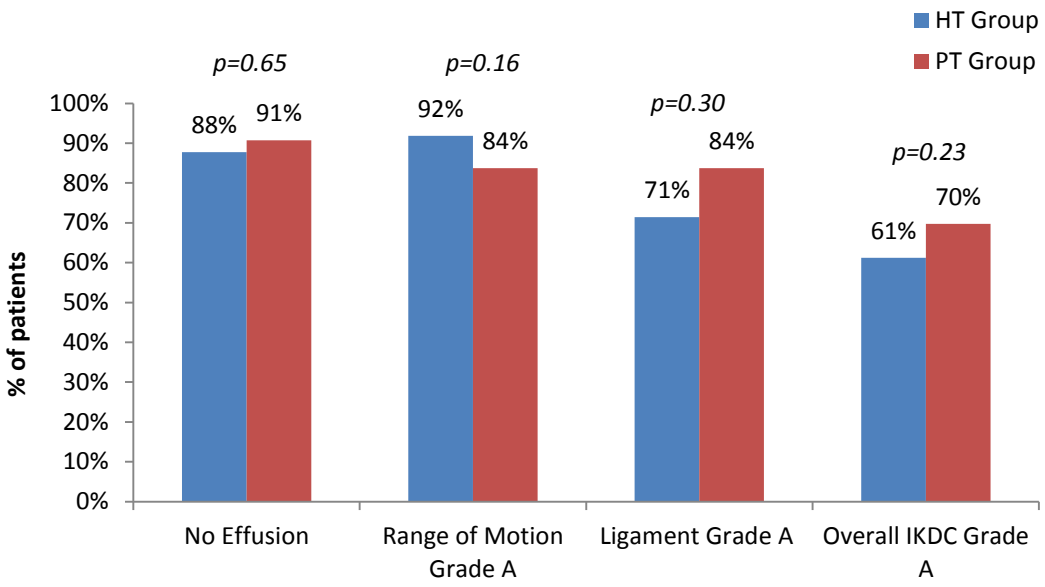
The single leg hop test measures the distance achieved by a single leg hop on the reconstructed leg compared to a hop on the contralateral normal leg, expressed as a percentage. A grade A hop equates to a distance 90% or greater than the contralateral limb. Grade B is 75 to 89%, and grade

C is less than 75%. In the HT group 77% (n=33) achieved a grade A and 23% (n=10) achieved grade B. In the PT group 85% (n=35) percent achieved grade A and 15% (n=6) achieved grade B.

Overall IKDC

The overall IKDC gives a grade after assessing the 4 subgroups, including function, symptoms, range of movement, and laxity. The results give a grade of A, B, C or D for each of the subgroups, and the worst rating is used to determine the overall IKDC grade. This is a very conservative measurement, as only a completely normal knee achieves grade A. Figure 10 demonstrates the percentage in each group, and shows no significant difference between the HT and PT groups (p=0.23).

Figure 10: Percentage with a Normal (Grade A) IKDC at 20 years



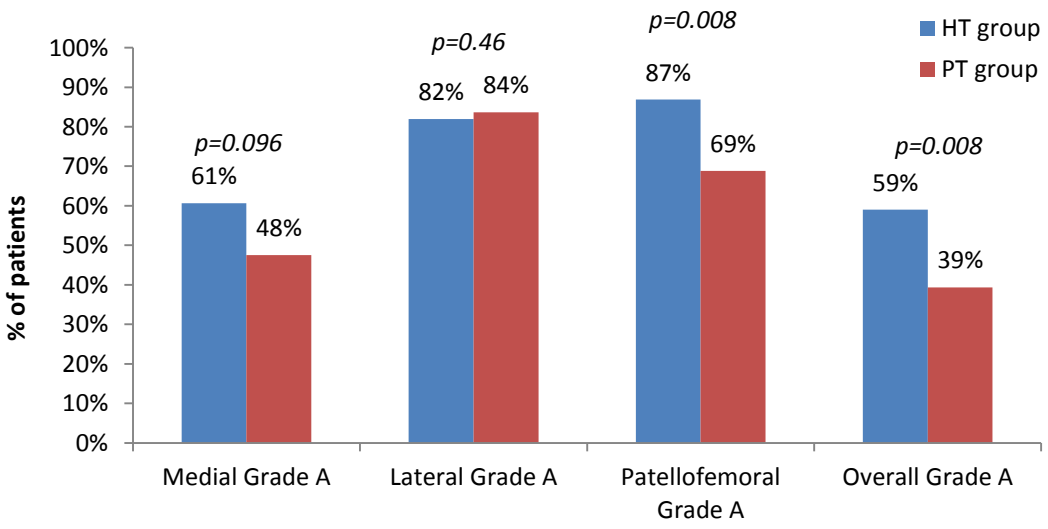
If patients with ACL graft rupture are assumed to have an abnormal overall IKDC evaluation then in the proportion of subjects with normal or nearly normal (Grade A or B) overall IKDC ligament

evaluation at 20 years was 74% (48 of 65) in the HT group and 76% (40 of 52) in the HT group (p=0.752).

RADIOGRAPHIC RESULTS

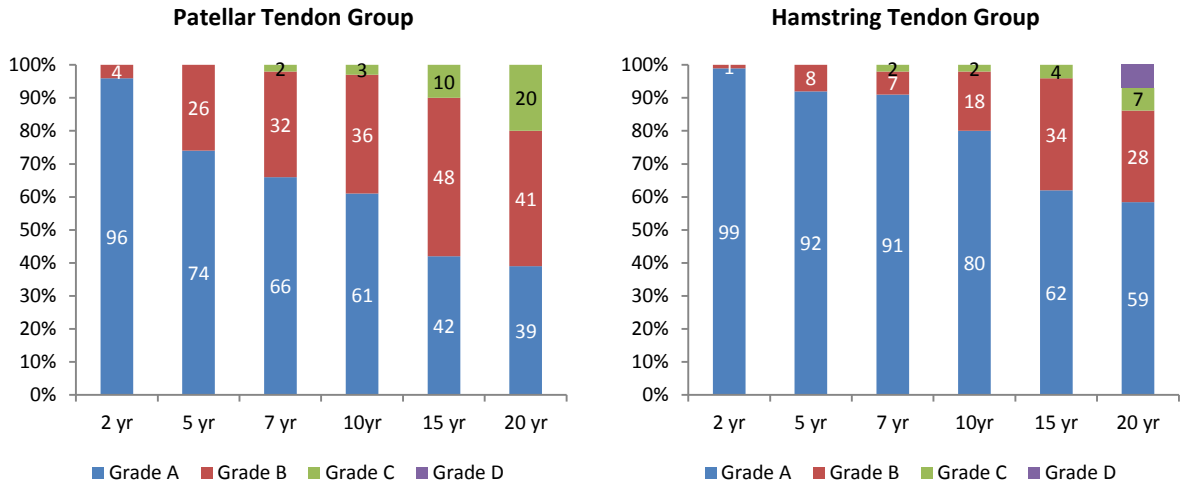
At the 20 years, there were a total of 122 patients that had radiographs performed, 61 in the HT group and 61 in the PT group. A normal or nearly normal overall IKDC Radiographic grade was found in 87% (n=53) of the HT group and 80% (n=49) of the PT group (p=0.328). The percentage of subjects with a Grade A Radiological IKDC grade in each compartment is shown in Figure 11.

Figure 11: Percentage of Patients with IKDC Grade A Radiological Grade at 20 years by compartment



The proportion of subjects with an abnormal IKDC radiographic grade was significantly higher in the PT group than the HT group at 5 years (p=0.02), 7 years (p=0.005), 10 years (p=0.04), 15 years (p=0.04) and 20 years (p=0.008) (Figure 12).

Figure 12: IKDC Radiological Grade in the Patellar and Hamstring Tendon Groups at years 2 to 20 years



The influence of the factors of graft type, further surgery and tunnel placement were assessed with regression analysis on the outcome of overall radiographic grade. Ideal tunnel position was not associated with radiographic outcome (p=0.838). Further surgery increased the odds of abnormal radiographic grade by a factor of 2.6 (95% CI 1.1-6.1, p=0.03). Use of the PT graft increased the odds of having an abnormal radiographic grade by a factor of 2.4 (95% CI 1.2-5.2, p=0.019), compared to those who received the HT graft.

Tunnel Position

Tunnel position was measured and classified overall as ideal or non-ideal, according to the criteria outlined in the methods. There were 174 out of 180 x-rays reviewed for tunnel position measurement with 89 from the HT group and 85 from the PT group. The mean values for tunnel placement are shown in Table 7.

Table 7: Comparison of Tunnel Placement Parameters between Hamstring and Patellar Tendon Groups

Mean Tunnel Position (Standard Dev)	Hamstring Tendon Group	Patellar Tendon Group	P Value
No of patients	89	85	
Posterior Femoral (Sagittal View)	84 (5)	82 (5)	0.032
Anterior Tibial (Sagittal View)	49 (4)	44 (5)	0.003
Graft Inclination (Coronal view)	19 (4)	21 (5)	0.076

Ideal sagittal femoral placement has been described as greater than 80% posterior along Blumensaats line. In the HT group 85% (n=76) were ideally placed and in the PT group and 67% (n=57) were ideally placed (p=0.004).

Ideal graft inclination angle has been described as greater than 17 degrees from the vertical. Graft inclination of greater than 17 degrees was found in 69% (n=60) of the HT group 69% and 78% (n=65) of the PT group (p=0.114).

Ideal sagittal tibial tunnel placement has been described as 40 to 50% anterior along the tibial plateau line. In the HT group 60.7% (n=54) were ideally placed. In the PT group the 71.8% (n=61) were ideally placed. There was no significant difference in ideally placed sagittal tibial tunnel position (p=0.083)

Overall ideal position requires all three measurements to be ideal. In the HT group 37.1% (n=33) had an overall ideal tunnel position. In the PT group 38.8% (n=33) had an overall ideal tunnel position. There was no difference in the number of ideal tunnel positions between the two groups (p=0.468).

GENDER DIFFERENCES

Table 8 shows the outcomes sub grouped according to graft and gender.

Table 8: Differences between subgroups of male and female for both graft choices.

	Female Patellar	Male Patellar	Female Hamstring	Male Hamstring	P value
ACL Graft Rupture (%)	2%	17%	16%	19%	0.081
Contralateral ACL Injury	23%	35%	9%	19%	**0.033**
Mean IKDC Subjective Score	83	90	88	91	0.017
Strenuous or Very Strenuous Activity without Pain	67%	88%	85%	84%	**0.047**
Regular Participation in Strenuous or Very Strenuous Activity	49%	65%	65%	63%	0.44
Kneeling Difficulty	43%	32%	26%	12%	**0.043**
Overall Ligament Grade A	96%	71%	68%	76%	0.258
Normal Overall IKDC Grade	86%	52%	61%	62%	0.072
Normal Overall IKDC Radiographic Grade	39%	40%	66%	52%	**0.003**

DISCUSSION

There is a paucity of studies comparing the long-term outcome of endoscopic ACL reconstruction using modern techniques. This study reports the outcomes at 20 years of ACL reconstruction comparing the use of HT against PT, the longest reported follow up in the literature. Our results support the hypothesis that long term outcome of ACL reconstruction is effected by graft selection.

Osteoarthritis

Associated injuries in the knee can result in sub-optimal outcomes following ACL reconstruction. Chondral damage or meniscal pathology increase the rate of osteoarthritis in the knee. This research studies an isolated ACL injury, removing the effect of known confounders of significant chondral and meniscal pathology, allowing meaningful comparisons of hamstring and patellar graft with regarding OA.[11, 17, 20, 32, 42] At 20 years there was a higher incidence of detectable radiological OA in the PT group (61%) compared to the HT group (41%). Other studies have shown progression of OA in the reconstructed knee being as high as 20% at 10 years. [1, 15, 30] However the proportion of subjects with moderate to severe radiographic degenerative changes was small in this series, 20% of the PT group and 13% of the HT group at 20 years. As the mean age of the participants in this study at the 20 year review was 50 years of age, the incidence of OA after ACL reconstruction with regarding moderate to severe degenerative change, may be considered comparable to the normal population[48]. Our study may reveal lower rates of degenerative change compared to other series due to the selection of subjects without significant concurrent injuries to the menisci and articular cartilage. In randomized controlled trials of graft type, Sajovic et al. reported higher rates of OA with the PT graft compared to the HT graft at 5 and 11 years[39, 40], but Holm et al. no significant difference in the development of radiological OA

between HT an PT grafts at 10 years[19]. Our series represents the longest currently available review of endoscopic ACL reconstruction comparing graft types. The mechanism responsible for the higher rate of osteoarthritis seen with the patellar tendon graft compared to the HT graft is not clear, but others have demonstrated measureable and sustained differences in gait patterns and biomechanics after ACL reconstruction are graft specific [50].

ACL Graft and Contralateral ACL Injury

Further ACL injury after reconstruction is common, whether to the reconstructed knee or the contralateral knee. In this series further ACL injury to either the reconstructed or contralateral knee occurred in 30% of the HT group, and 37% in the PT group (p=0.343). While the incidence of further injury was equivalent between graft types, the side on which further ACL injury occurs was graft specific. ACL graft rupture occurred more commonly in the HT group, although this did not reach significance (18% in HT group, compared to 10% in the PT group, p=0.13). Conversely, contralateral ACL rupture occurred more commonly with the PT graft (30%) compared to the HT graft (14%) (p=0.035) and others have reported similar findings[44, 51-53] The reason for this is unknown. Possible reasons include the BPTB reconstruction is larger and stronger than the native knee ligament, or the contralateral knee is neglected during rehabilitation[53]. Alternatively, patients may favour the reconstructed knee, placing the native ACL at greater risk. Regardless of the side on which further ACL injury occurs, this is a devastating outcome for the patient. Although the surgical technique used in this series has remained relatively unchanged, we have significantly altered the rehabilitation protocols since the early 1990s. The implementation of modern rehabilitation protocols with a greater focus on pylometrics, agility and sports specific drills, as well as delaying a return to competitive sports for 12 months after reconstruction may positively influence the rate of further injury after ACL reconstruction and should be encouraged.

Clinical outcomes

Long term clinical outcomes were equivalent between graft types for the variables of self reported outcomes, IKDC grades, range of motion and activity levels at 20 years, which is consistent with previous studies. [22, 23].

Age

Those < 18 years at the time of ACL reconstruction had a 4.6 times greater odds of an ACL graft rupture and 3.4 times greater odds of a CACL rupture compared to those >18 years. Of the 29 patients aged 18 or less at the time of reconstruction, 18 (62%) sustained either an ipsilateral (n=7) or contralateral ACL injury (n=14) over the 20 year review (3 of the 29 sustained both an ACL graft rupture and a contralateral ACL injury). Other studies have also identified higher rates of further ACL injury in the young compared to their adult counterparts[33].[8, 27, 43, 52] Further ACL injury in the young was most common in the first 5 years after surgery where more than 50% of the injuries occurred. After 5 years from surgery the slope of the survival curves in the young more closely resembles that of the adult counterparts (Figure 4-5). Studies have shown that this adolescent group may be less complaint with rehabilitation, and more likely to take part in activities placing the ACL at risk (such as team contact sport participation)[2, 27], which would contribute to this increased risk of injury. The increased risk of native or reconstructed ACL rupture in the young could also be due to genetic predisposition, anatomical or biomechanical considerations of the juvenile knee.

Gender

The outcome of ACL reconstruction in this study was examined as factor of graft type and gender (Table 8). Others have reported poorer outcomes after ACL reconstruction in females compared to males.[45] Females who received a PT graft a displayed a trend towards the lowest rate of graft rupture (p=0.08) and highest incidence of a normal IKDC examination (p=0.07), but also had the

lowest mean IKDC subjective scores, highest incidence of pain with activity and greatest difficulty with kneeling and lowest level of sports participation. This may mean that the females with PT graft do not wish to indulge in activities causing discomfort and thereby precluding strenuous activity. Activity modification in this manner will place the graft at lower risk of graft rupture, compared to patient groups with higher subjective scores wishing to participate in contact and team sports (automatically engaging in activities associated with rupture risk). Males who received the PT graft had a significantly higher incidence of further ACL injury (p=0.05) and range of motion deficit (p=0.05), compared to the other groups.

Tunnel Placement

Currently there is still debate on the correct placement of both the femoral and tibial tunnels for ACL reconstruction. This study has shown that ideal sagittal femoral placement as being 80% along Blumensaats line, a graft inclination angle of greater than 17 degrees from the vertical, and sagittal tibial tunnel placement 40-50% along the tibial plateau. Femoral tunnel placement has recently been lower on the lateral wall of the intercondylar notch, but lower placement trends have not as yet revealed lower graft re-rupture rates.[4]

The limitations of this study are well documented[12, 24, 35], and the strict inclusion criteria attempts to produce a knee as close to an isolated ACL injury as possible. The lack of confounding factors or other injuries does not represent the entire population sustaining an injury of this nature, probably reflecting 30% of patients sustaining this injury pattern. It is therefore not generalizable to all ACL ruptures but rather represents the 'best case scenario'. The lack of randomization of graft type introduces the potential for bias. The strengths lie in the prospective longitudinal nature over a 20 year period and the very low rates of loss to follow up. The surgical technique was reproduced by a single experienced surgeon, eliminating multiple operator bias, utilizing a modern ACL reconstruction method for both autologous graft types.

CONCLUSIONS

Over 20 years endoscopic ACL reconstruction using either autologous HT or PT graft results with femoral drilling via the anteromedial portal is associated with excellent subjective outcomes and clinical ligamentous stability that are maintained, with high rates of continued participation in active sports. Regardless of graft type, ACL reconstructed patients have a high incidence of further ACL injury of over 30%. Graft rupture is strongly associated with a young age, non-ideal graft position and males. Injury to the contralateral ACL injury associated with young age and the use of the patellar tendon graft choice. HT graft patients have significantly lower incidence of kneeling difficulty and radiological osteoarthritis than their PT reconstructed counterparts. In so far that the operative procedure, radiological tunnel placement and short term clinical outcomes of the two graft choices are similar any significant differences in outcome are most likely attributable to graft choice. While both the hamstring and patellar tendon grafts can be considered viable choices, the prospective long term results in this series favour the hamstring tendon graft, over the patellar tendon graft, for the lower incidence of radiological osteoarthritis.

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