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Twenty-Year outcome of a longitudinal prospective evaluation of isolated endoscopic anterior cruciate ligament reconstruction with patella tendon autograft

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Abstract

Background: Long term prospective follow up studies of single-incision endoscopic anterior cruciate ligament reconstruction are limited and may include confounding factors.

Objectives: This longitudinal prospective study reports the outcome of isolated anterior cruciate ligament (ACL) reconstruction using middle-third patellar tendon autograft in 90 patients over 20 years.

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

Methods: Between January 1993 and April 1994, 90 patients met study inclusion criteria, evaluation 1,2,3,4,5,7,10,15 and 20 years post surgery. Exclusion criteria: associated ligamentous injury requiring surgery, previous meniscectomy; meniscal injury meniscectomy more than 1/3; chondral injury; and an abnormal contralateral knee.

Results: At 20 years, 32(36%) patients had sustained another ACL injury, 8(9%) to the index limb and 27(29%) to the contralateral limb (3 injuring both knees). Mean IKDC score was 86, 50% participated in strenuous/very strenuous activities, kneeling pain was present in 63%. Radiographic degenerative change was found in 61%, 20% IKDC Grade C, 0% Grade D. IKDC clinical examination revealed 95% had a normal/nearly normal knee. Significant gender differences existed: females were less likely to re-injure the reconstructed ACL (18%v2%, p=0.01), reported poorer IKDC subjective score (90v83, p=0.03), had more activity related pain (57%v20%, p=0.02), and less likely to participate in strenuous activity (35v66, p=0.01). ACL graft survival was not related to age. Patients <18years old had an increased odd ratio (3.2) for rupturing the contralateral ACL. Coronal graft angles <17 degrees had increased risk of failure compared to those over 17 degrees (96% v 77%), by a factor of 8.5.

Conclusion: Injury commonly occurred in the contralateral ACL than the reconstructed ACL graft, the most significant predictor of contralateral ACL injury is age under 18yrs. The most significant

predictor of ACL graft rupture is a coronal graft angle of less than 17 degrees. Females had lower re-rupture rates, poorer subjective scores, decreased participation in strenuous activity, putting the graft at less risk of failure. Kneeling pain remained persistent over 20 years. Radiographic osteoarthritis was evident in 61% of subjects but symptomatic osteoarthritic symptoms were rarely reported.

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

Clinical Relevance: The literature suggests that there is not enough evidence to determine the long-term outcome of ACL reconstructive surgery using patella tendon, specifically with regards to arthritis and functional outcome. This study reports the outcomes of ACL and contralateral ACL knee injury at 20 years, allowing patients to better understand the long term effects of ACL reconstruction and the possibility of further injury to the uninjured knee.

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 patella 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

Injury to the anterior cruciate ligament may lead to recurrent episodic instability, pain, meniscal injury, osteoarthritis, poor quality of life and adversely affect long-term function of the knee.[6, 7, 10, 11, 21, 28, 30, 39] Endoscopic reconstruction aims to provide the patient with a stable knee, by means of reproducing the anatomy of the ACL, thereby reducing the potential for adverse long term intra-articular sequelae[21]. Arthroscopic reconstruction is considered the gold standard for the treatment of ACL rupture[9, 14, 23, 27]. The literature would tend to suggest that there is not enough evidence to determine whether reconstruction of the ACL prevents arthritis in the long-term[13, 16, 21, 29].

Few studies have reported long-term outcomes of single incision, endoscopic reconstruction of the ACL without the associated other pathologies including meniscal, collateral ligament and chondral surface damage[7, 22, 27, 37, 38]. This prospective study excludes these confounding factors, and has been reported in the literature at 2,5,7,10,15 years post-surgery[12, 33-36]. The purpose of this study is to report the 20-year outcomes of isolated ACL rupture treated with endoscopic reconstruction using middle-third patellar tendon autograft.

METHODS

Patient Selection

Between January 1993 and April 1994, 333 consecutive patients underwent ACL reconstruction. All patients had an ACL rupture diagnosed on clinical examination and confirmed at arthroscopy and wished to return to sports involving pivoting, cutting or sidestepping; or they had repeated episodes of instability despite non-operative treatment and appropriate rehabilitation. Exclusion criteria included: any associated ligament injury

requiring surgery, evidence of chondral damage or degeneration, previous meniscectomy or meniscal injury requiring more than one-third meniscectomy at the time of reconstruction, abnormal radiograph, abnormal contralateral knee, patients seeking compensation for their injury and patients who did not wish to participate in a research study. Therefore, the study group consisted of 90 patients with an essentially isolated ACL injury. Ethical approval was obtained from an independent ethics committee.

Surgical Technique

The operative technique was standardized in all patients and has previously been described in detail[41]. The senior author performed all procedures. Examination under anaesthesia confirmed anterolateral rotary instability and positive Lachman testing in all patients. Under general anaesthesia, a single dose of intravenous cephalosporin was administered. The limb was exsanguinated using an esmarch bandage and a high thigh tourniquet was used. Diagnostic arthroscopy was performed first, using high anterolateral and low anteromedial portals. Suturing of appropriate meniscal lesions was carried out using an inside-out technique. A central-third patellar tendon autograft was harvested through two 2cm longitudinal incisions at the distal aspect of the patella and just medial to the tibial tubercle. The femoral tunnel positioned 5mm anterior to the posterior capsule insertion and was drilled through the low anteromedial portal with the knee in maximum flexion. The tibial tunnel was positioned on the line between the anterior tibial spine and the anterior horn of the lateral meniscus, immediately anterior to the PCL. The graft was fixed on the femoral side with a 7 x 25 mm round-headed cannulated interference (RCI) screw (Smith and Nephew Acufex, Mansfield, MA) through the low anteromedial portal and a 7 x 25 mm RCI

screw on the tibial side. The osseous tunnels were drilled 1mm less than the diameter of the graft. The mean diameter of the tunnel was 9.6mm (range 8-11mm). Final tibial graft fixation was performed in full extension. Full hyperextension, stable Lachman and anterior drawer tests were achieved under anaesthetic in all patients.

Post-operative Protocol

Patients were admitted to hospital for a median of 2 nights (1-5 nights). Immediate weight bearing with the aid of crutches was encouraged. The median time of crutch use was 10 days (2-21 days). An accelerated rehabilitation program commenced on post-operative day 1 to reduce pain and swelling with the goal of achieving full extension by 6 weeks. The rehabilitation program included closed-chain exercises with an emphasis on proprioceptive training. At 6 weeks, patients began jogging in straight lines. From 12 weeks, general strengthening exercises were continued with agility work and sporting activities encouraged. Return to competitive sport involving jumping, pivoting or sidestepping was not permitted until 6 to 9 months after surgery.

Clinical Assessment

Assessments were performed by independent physical therapists or researchers with extensive experience in knee assessment. Clinical assessment included: ROM, ligament stability, instrumented knee testing using the KT-1000 arthrometer (MEDmetric Corp, San Diego, Ca) using the manual maximum test, the International Knee Documentation Committee (IKDC) Knee Ligament Evaluation Form[4, 8]. Ligament stability was measured by the Lachman and pivot-shift tests[25]. The Lachman was graded as: 0 (negative), 1 (1-5mm

laxity), 2 (6-10mm laxity) or 3 (>10mm laxity) and the pivot-shift test as: 0 (negative), 1 (glide), 2 (clunk) or 3 (gross). Subjective assessment included: the Lysholm knee score and IKDC subjective knee function score.[4, 8] The single-legged hop test was used for functional assessment. Evaluation was conducted pre-operatively, annually for 5 years, then at 7, 10, 15 and 20 years after surgery, these were side to side comparisons.

Radiographic Assessment

Radiographic examination was performed as a side to side comparison, using bilateral weight bearing 35-45˚ postero-anterior (PA), antero-posterior (AP), lateral, and patellar skyline views. Radiographs were classified according to the IKDC guidelines as follows: 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. This grading has been shown to be both reliable and reproducible with longitudinal data[25]. An experienced musculoskeletal radiologist graded all radiographs. Tunnel position was assessed in the sagittal and coronal planes and the graft inclination angle was measured using a method that has previously been described in detail[35].

Statistical Analysis

All data was assumed to be non-parametric. The Wilcoxon signed ranked test was used to assess change over time. Comparisons between subgroups were performed with the Mann-Whitney U test. Logistic regression analysis was used to assess the relative contribution of selected variables on dichotomous outcomes. Statistical significance was set at p=0.05. SPSS 11.0 for Windows (SPSS Science Inc., Chicago, Il) was used for all the above statistical

analysis. The outcomes were compared between sexes using the Mann-Whitney U test for continuous measurements (mean KT-1000 arthrometer, Lysholm score) and the $\chi 2$ test for ordered categorical variables (IKDC categories, Lachman, pivot-shift test). Logistic regression was used for the relationship between radiologic outcomes and the variables of further surgery and tunnel placement. Survivorship of the ACL graft and contralateral ACL was calculated using the Kaplan-Meier survival method. Comparisons of survival curves were made with log-rank tests and univariate Cox Regression. The influence of the factors of age <18 years, family history, gender and graft angle on ACL graft survival were assessed. The influence of the factors of age <18 year and gender on contralateral ACL survival were assessed. Factors that were significant ($p<0.05$) on univariate survival analysis were entered into multivariate Cox regression and then eliminated in a step-wise fashion, until only the independent significant factors remained. Statistical significance was set at a 5% level.

RESULTS

Study Group

Ninety patients met the inclusion criteria. There were 46 men (51%) and 44 women (49%). The left side was involved in 35 patients (39%) and the right in 55 (61%). Mean age at the time of reconstruction was 25 years (15-42 years). Reconstruction was performed within 3 weeks of injury in 3 patients (3%), between 3 and 12 weeks in 64 (71%) and after 12 weeks in 23 (26%). All patients had a preoperative Lachman test of grade 1 or 2 and 94% had a positive pivot-shift; the remainder had locked knees and a pivot shift could not be performed. Three patients (3%) with an acute injury had grade 2 laxity of the medial collateral ligament; all were successfully treated by a preoperative hinged ROM brace with

an extension block at 30˚ for 6 weeks. Seventy-seven patients (86%) had intact menisci at the time of ACL reconstruction. Seven (8%) required meniscal suture at the time of surgery and 6 (7%) required excision of less than one-third of the meniscus.

Further ACL Injury

Overall, **32** patients **(36%)** sustained a subsequent ACL injury, either ACL graft rupture or contralateral ACL (CACL) injury, at 20 years. Eight patients (9%) ruptured the ACL graft at a median time of 82 months (12-240 months) post-operatively. These patients subsequently underwent revision ACL reconstruction. ACL graft rupture occurred in 7 males and 1 female.

Twenty-seven patients had a contralateral ACL rupture at a mean of 82 months post-operatively (22-165 months). These patients were excluded from subsequent instrumented testing and single-legged hop test data, which assumes a normal contralateral knee. 25 of 27 contralateral ACL ruptures underwent ACL reconstruction. There were significantly more contralateral ACL ruptures than graft ruptures over the 20-year follow-up period (p=0.01). 3 patients sustained both an ACL graft and contralateral ACL injury.

Complications

There was 1 superficial wound infection in the proximal wound of the graft harvest that was treated successfully with oral antibiotics. Two patients developed patellar tendonitis at 9 and 23 months post-operatively and were treated successfully with analgesia and physiotherapy. 37 patients had further surgery. In 22 patients, surgery was performed on

the contralateral knee. 13 patients had surgery to the reconstructed knee and 6 required surgery to both the reconstructed and the contralateral knee, Table 1. In total there were 9 meniscectomies performed after ACL reconstruction over the 20-year period. All meniscal tears occurred during sporting activities. One patient died of unrelated causes at 9 years post-operatively. 4 patients had contralateral meniscectomies. These occurred at 44, 72, 96 and 99 months in each patient respectively.

Follow-up

Mean follow-up time was 245 months (231-259 months). 80 subjects were reviewed at 20 years. Of the 10 subjects not reviewed, 1 died of unrelated causes, 3 refused research participation, 2 were unable to be located and 4 did not attend. The participant flow is shown in Figure 1.

Patients who sustained rupture of the ACL graft were reviewed and a summary of their results is shown in Table 2. Reviews were therefore performed on 72 of a possible 81 patients (89%) at 20 years.

Self-reported Assessment

Lysholm Knee Score

The Lysholm knee score is designed to evaluate specific symptoms relating to knee function (limp, need for support, locking, instability, pain, swelling and impairment of stair-climbing or squatting ability). The best score is 100. Pre-operative median Lysholm knee score was 64 (range 6-97). At 20 years, the median Lysholm knee score was 95 (range 55-100).

Subjective Knee Assessment (IKDC)

At 20 years post-surgery the mean subjective IKDC score at 20 years was 86 out of a possible 100 (range 28-100).

Activity

At 20 years after surgery, the average age of the patients was 45 years. Regular participation was: 35% (n=25) in very strenuous activities such as soccer and basketball, 15% (n=11) in strenuous activities such as skiing or tennis, 38% (n=27) in moderate activities such as running or jogging and 13% (n=9) in light activities such as walking.

Symptoms with activity

At 20 years after surgery, very strenuous or strenuous activities could be performed: without pain in 78% (n=56) of patients, without swelling in 76% (n=55) of patients and without giving way in 88% (n=63) of patients.

Kneeling pain

The proportion of patients with kneeling pain or difficulty is reported in Figure 2. There was a significant increase in the incidence of kneeling pain between 2 and 20 years (p=0.001).

Gender analysis

Females demonstrated significantly lower incidence of ACL graft rupture compared to males, but also poorer subjective outcomes and lower reported activity levels as shown in Table 3.

The proportion of males and females participating in strenuous activities at each review is shown in Figure 4. Greater proportion of males reported participating in strenuous sports at 2 years (p=0.09), 15 years (p=0.01) and 20 years (p=0.009)

Males had higher mean Lysholm score than females at 2 years (p=0.05), 5 years (p=0.06), 10 years (p=0.09), 15 years (p=0.008) and 20 years (p=0.20) (Figure 5).

Clinical Assessment n=44

IKDC clinical assessment assumes a normal contralateral ACL. At 20 years after surgery there were 57 living subjects with an intact ACL graft and contralateral ACL eligible for 20 year review. Review was performed on 44 of 57 (77%) at 20 years. Of the 13 subjects without clinical review 6 had moved interstate or overseas and were unable to attend for geographical reasons, but did complete subjective review, 3 refused ongoing participation in research, 2 did not attend and 2 were unable to located. The results are summarised in Table 3.

<u>Range of Motion</u>

At 20 years after surgery, 39/44 had extension within 3 degrees of the contralateral limb. 4 patients had 3-5 degrees loss of extension and 1 patient had 10 degrees loss of extension. The subject with 10 extension loss was a 43 year old male, with IKDC grade C grade on radiographs and a subjective IKDC score of 89. 43 of 44 patients had flexion range within 5 degrees of the contralateral limb and 1 patients had 25 degree flexion loss. The patient with 25 degree flexion loss had a recent knee injury and MRI and clinical findings consistent with

a medial meniscal tear. The percentage of patients with extension loss increased significantly between 2 and 5 years (p=0.002), but there was no change between 2 and 20 years (p=0.46)

Single-Legged hop Test

The single-legged hop test of knee function determines the percentage of the distance achieved by hopping on the involved limb compared with the contralateral normal limb. 2 subjects did not perform the assessment due to recent ankle or hip injury. 35 subjects (n=83%) were able to hop $\geq$ 90% of the contralateral limb, and 17% (n=7) were able to hop between 76 and 89% of the contralateral limb.

Ligament Testing

Table 3 demonstrates the percentage of patients with normal (0-2mm laxity) or nearly normal Lachman (3-5mm laxity), pivot-shift tests and instrumented testing at 20 years.

Overall IKDC Grading

Table 3 shows the 20-year IKDC grade for the 3 subgroups effusion, range of motion and ligament evaluation, and the overall IKDC grade. Overall IKDC score is a very conservative scale because the worst rating of any item in a given group determines the overall group rating. Therefore, only patients with a normal knee will be rated class A.[26]

Radiographic Assessment

Radiographs were reviewed in 61 patients. The compartment with the most degenerative changes determines the overall IKDC radiographic grade. Results are shown in Figure 3 and

Table 5. Overall, 61% had evidence of OA at 20 years after surgery. However, only 20% of subjects showed Grade C changes at 20 years, no Grade D findings.

Radiological tunnel placement (n = 85)

85 of 90 patients had a suitable post-operative radiograph available for measurement of radiological tunnel placement using the previously described method[22](Table 6).

Survival Analysis

ACL graft survival was 96%, 94%, 94%, 90% at 5, 10, 15 and 20 years after ACL reconstruction (Figure 6) Survival of the contralateral ACL was 86%, 75%, 71%, 67% at 5, 10, 15 and 20 years after ACL reconstruction (Figure 9).

If the coronal graft angle was < 17 degrees the odds for ACL graft rupture were increased by a factor of 8.5, compared to those with a coronal graft angle of 17 or more (95% CI 2-47, p=0.01) (Figure 7). 20 year survival of the ACL graft was 96% in those with an graft angle of 17 or more, and 77% in those with a graft angle of <17 degrees. On multiple regression analysis ACL graft survival was not significantly effected by the factor of age <18 at the time of reconstruction (OR 1.1, 95% CI 0.1-9.8, p=0.91), family history of ACL injury (OR 2.0, 95% CI 0.5-8.2, p=0.35), or gender (OR 7.1, 95% CI 0.8-62, p=0.08).

Regression analysis of CACL survival showed that patients <18 years had a 3.2x greater odds of CACL rupture than those over 18 years (95% CI 2.3-22.8, p=0.001) The survival of the

contralateral ACL was 44% in those <18 years, compared to 75% in those 18 or more (Figure 8). CACL survival was not influenced by gender (OR 1.1, 95% CI 0.3-3.0, p=0.92), or family history of ACL injury (OR 1.1, 95%CI 0.5-2.8, p=0.79).

DISCUSSION

This study reports the 20-year outcomes of endoscopic ACL reconstruction using middle-third patellar tendon autograft. It is known that other associated pathologies in the knee (such as chondral damage) can result in a poor outcome despite ACL reconstruction. This study reporting the findings of 'isolated' ACL injuries requiring reconstruction, based on the adopted exclusion criteria. It is, however, noted that it is difficult to achieve this in reality and that the truly 'isolated' ACL probably does not occur. The strict inclusion criteria resulted in approximately 30% of patients with ACL rupture over the study period being eligible for the study. Interpretation of the outcomes of this study cannot be generalised to the wider population of ACL injured knees, but rather represent the best-case scenario after ACL reconstruction.

Osteoarthritis

The long term role of ACL reconstruction preventing OA has not been well established in the literature, but its role in menisco-protective functioning preventing further damage to the menisci has been shown in several studies[10, 38]. In this series 9 patients required further meniscectomy, 6 of which were performed in the first 15 years following reconstruction and 3 meniscectomies were performed between the 15-20 year period. By comparison 4 patients underwent meniscectomy in the contralateral knee. In a prospective study of

conservatively treated ACL's the incidence of meniscal surgery was 54% over 5 years, and in other studies reported as high as 95% at 20 years post injury[17, 28]. Our findings support the hypothesis that ACL reconstruction is effective in reducing further meniscal damage, compared to conservative treatment.

Our results suggest that BPTB ACL reconstruction is not as arthogenic as previously suggested in the literature[15, 29]. In this series radiological degenerative change was present in 27% subjects at 5 years, 51% at 15 years, and 61% at 20 years. However the proportion of patients with moderate to severe changes was low, only 20% of subjects had Grade C (up to 50% joint space narrowing) changes at 20 years, and no Grade D. This in contrast with other studies looking at the progression of OA in ACL reconstructed knees, where higher levels of more severe degenerative changes are seen, some as high as 20% at 10 years with moderate to severe radiographic changes[1, 15, 29]. The presence of other pathologies in the knee such as chondral injuries or meniscal tears may increase the rate and degree of OA[11, 20, 21, 28, 31, 32, 39], and this may account for the lower incidence reported in our series compared to others. It should be remembered that the cohort of subjects in this study would now be an average age of 45 years. Others have shown that in the painful knee population the incidence of radiographically detectable OA in the 35-54 year age group is 5%[32]. BPTB ACL reconstruction does not appear to be associated with high rates of moderate to severe radiological degenerative change over 20 years, but it may be higher than the incidence seen in the general population, suggesting that this procedure does not prevent osteoarthritis, but may reduce the severity of premature degeneration when the meniscus is preserved.

Clinical Outcomes

Clinical outcomes reveal that 95% of subjects with intact ACL grafts had a normal or nearly normal knee at 20 years according to IKDC criteria. High subjective scores are maintained over 20 years, and normal ligament examination was seen in 84%. With regards to ROM only 1 patient had a loss of extension $>5^0$ and there was no statistically significant progression of loss of extension between 2 and 20 years, which is consistent with previous studies[23, 24]. At 20 years 50% of patients were back to strenuous activity, which suggests that ACL reconstruction with BPTB is an effective procedure for getting subjects back to sporting activity. Kneeling pain is a persistent issue post surgery despite a two incision approach. It is important to document that this common post-operative finding persists in up to 67% at20 year follow up, so must be addressed as part of the patients education on this procedure. ACL reconstruction with a BPTB is a well tolerated procedure with good clinical and subjective outcomes maintained over 20 years.

Gender differences

Females in this study demonstrated unfavourable outcomes compared to males with respect to lower IKDC subjective score, were more likely to report pain on strenuous exercise and were less likely to participate in strenuous activity. Females also had a lower incidence of ACL graft rupture (2%) compared to males (16%) (p=0.03), although gender did not achieve statistical significance on multiple regression analysis of ACL graft survival (p=0.08). Poorer subjective outcomes seen in females compared to males may preclude activity at a strenuous level, thereby limiting the reconstructed ACL exposure to activities

which could place the graft at risk of failure, and result in lower incidence of graft rupture. ACL reconstruction with BPTB has a favourable outcome for females compared to males with regards to ACL graft rupture but may be poorly tolerated with respect to subjective outcomes.

Further ACL Injury

Contralateral knee ACL rupture occurred more frequently than ACL graft rupture. The survival of the contralateral ACL was 69% at 20 years, compared to 90% in the reconstructed ACL. Previous studies have that reported ACL rupture rates of BPTB of 6-13% between 10-15 years[23, 40]. The higher incidence of contralateral ACL injury, compared to ACL graft rupture could be due to a number of factors, including the potential genetic and biomechanical considerations putting the native ACL at risk, the possibility of the subject favouring the reconstructed knee or the fact that the BPTB reconstruction is stronger than the native ligament.

Outcome after ACL graft rupture and revision surgery

Subjects who had a BPTB graft rupture had a higher incidence of radiological degenerative change (71%) compared to those with intact ACL grafts (60%), however their mean subjective scores were still high at 20 years (mean 84). The outcomes of failed BPTB reconstructions may be associated with slightly higher incidence of degenerative change but not necessarily poorer subjective outcomes

Tunnel placement

It is documented that a common cause for failure of ACL reconstruction is suboptimal positioning of the bone tunnels in both femur and tibia[35]. At 20 years the ACL graft survival was significantly lower in those with a coronal graft angle of less than 17 degrees, with an 8.5 times greater odds ratio, compared to those with a graft angle of >17 degrees. More vertical graft placement is associated with increased failure, due to persistent anterolateral rotational instability[2, 19]. Over recent years there has been a trend towards placing the femoral tunnel lower on the lateral wall of the intercondylar notch[5, 18]. The mean coronal graft angle was 19 degrees in this series, which may be higher than current trends. Whether the current trend for lower placement of the femoral tunnel on the intercondylar notch results in lower rates of ACL graft rupture is yet to be shown.

Age

When compared to those over 18 years, subjects under 18 years at the time of ACL reconstruction did not have higher rates of ACL graft rupture, but did have higher rates of contralateral ACL rupture. More than half of those <18 years (56%) had a contralateral ACL rupture over the 15 years. Other studies have shown that adolescents may well have a higher risk of ACL graft rupture, that they may have a higher preoperative activity level, issues with compliance with rehabilitation and be more likely to place the graft at risk[3, 26]. Our study has not shown the ACL graft survival to be significantly lower in adolescents than adults. However, the strongest predictor of contralateral ACL rupture was age less than 18, compared to over the age of 18 (25% v 56%). This could be due to mutifactorial aspects of this age group, including pre-existing genetic or biomechanical factors placing the native ACL

at risk, that the BPTB graft is stronger than the native ACL. Patients may also favour the reconstructed knee, placing the contralateral knee at increased risk of injury.

There are some limitations to this study. The strict inclusion criteria was designed to examine and report the natural history of ACL reconstruction without the confounding effects of other injuries. It must be noted that this represents approximately 1 in 3 of the ACL reconstructed population and the results of this study are not generalisable to those with confounding injuries, such as meniscal or cartilage damage, which is likely to worsen outcome. The strengths of this study include the very high follow up over 20 years, the prospective longitudinal deign, and the homogenous group of patients, treated by a single highly experienced knee surgeon ensuring consistency in surgical technique. The arthroscopic surgical technique reported in this study is consistent with modern techniques, with femoral tunnel drilling via the anteromedial portal.

CONCLUSIONS

This study reports the long term outcome of patients having undergone middle-third BPTB reconstruction at 20 years. In the reconstructed knee good long term outcomes with regards to subjective scores, return to strenuous activity governed by a stable knee with good ROM are demonstrated. We have shown that females may have unfavourable outcomes with regards to subjective scores and pain, which may protect the ACL graft from further injury. Radiological assessment of graft inclination angle is an important predictor of ACL graft rupture, contralateral ACL injury is common, especially in the young, and OA progression may not be as common as previously suspected.

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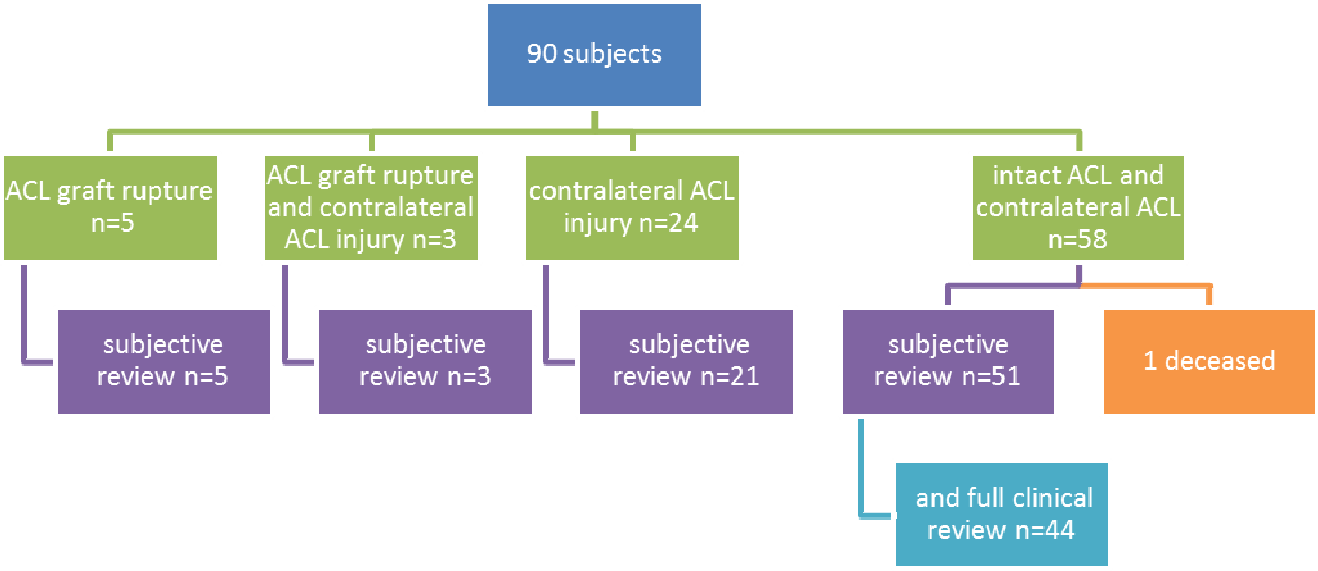
559 **FIGURES**

560 **Figure 1:** Participant Flow



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564 **Figure 2:** Percentage of patients with kneeling pain or difficulty at each review

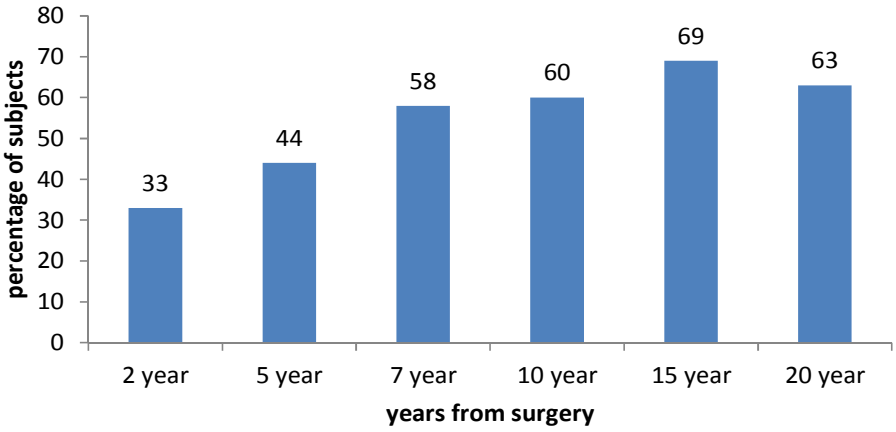

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Figure 3: Overall IKDC Radiological Grading

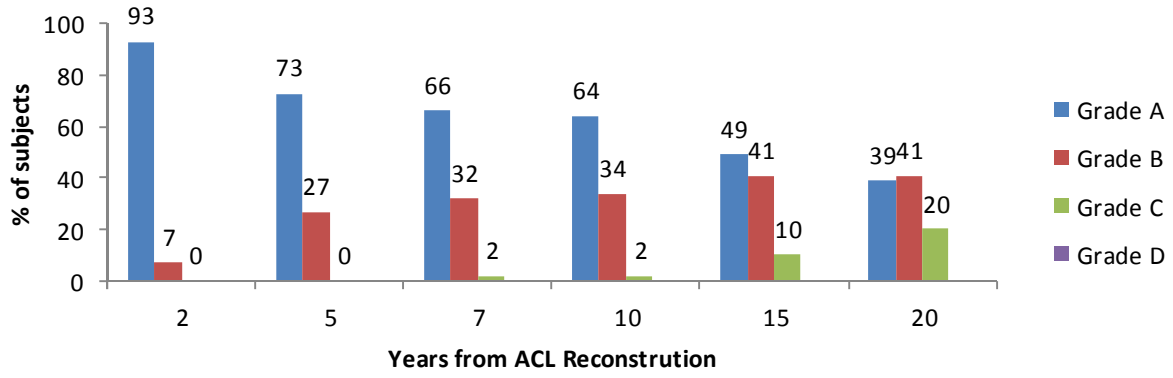
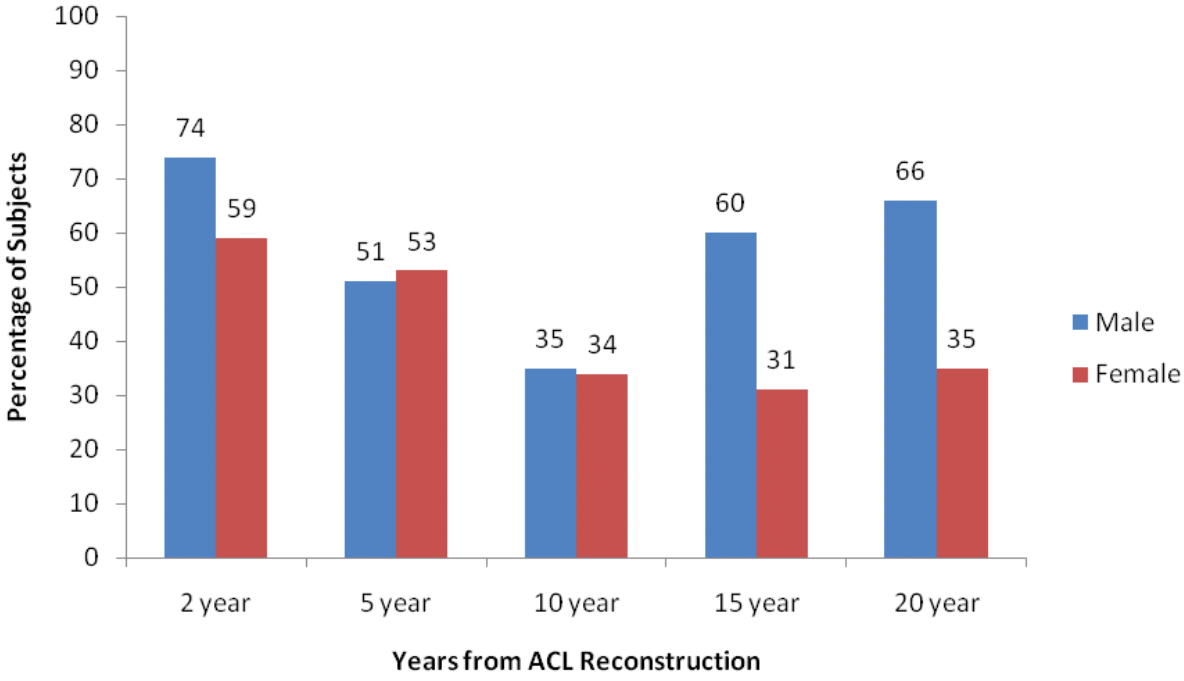
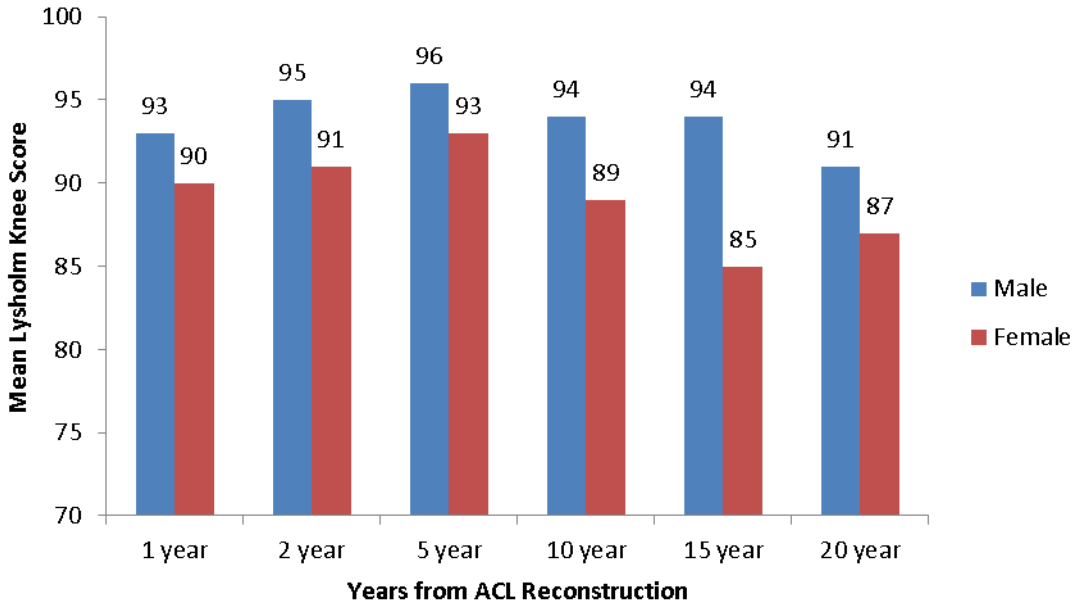


Figure 4: Percentage of males and females participating in strenuous sports at 2-20 years after reconstruction



583 **Figure 5:** Mean Lysholm Knee Score of males and females at 2-20 years after

584 reconstruction



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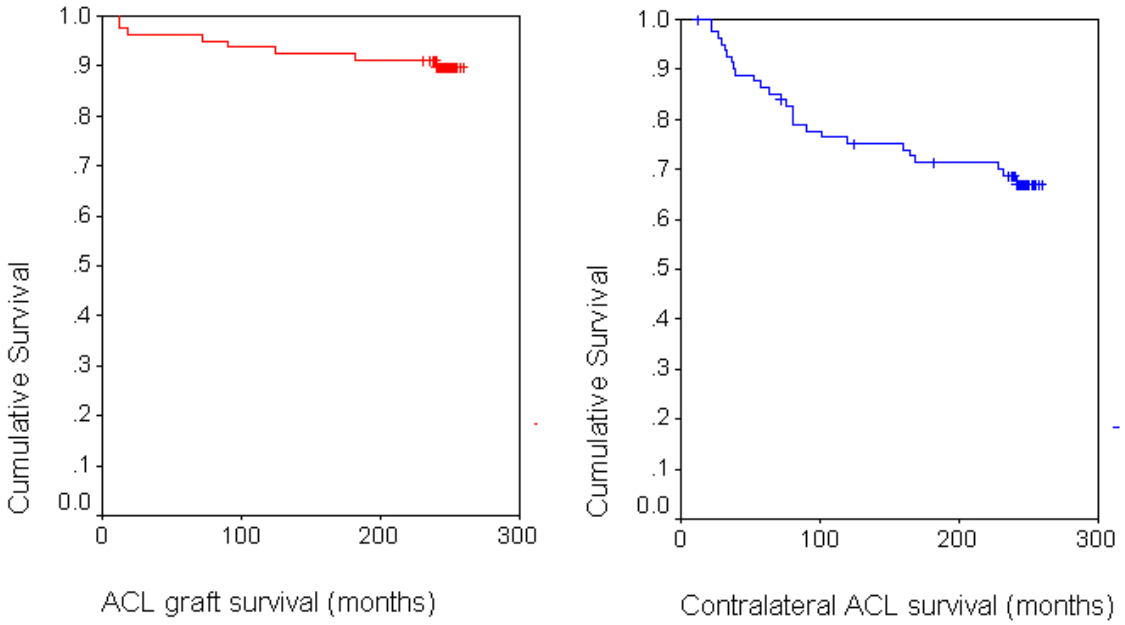
586 **Figure 6:** Kaplan Meier ACL graft (left) And Contralateral ACL (right) survival over 20 years



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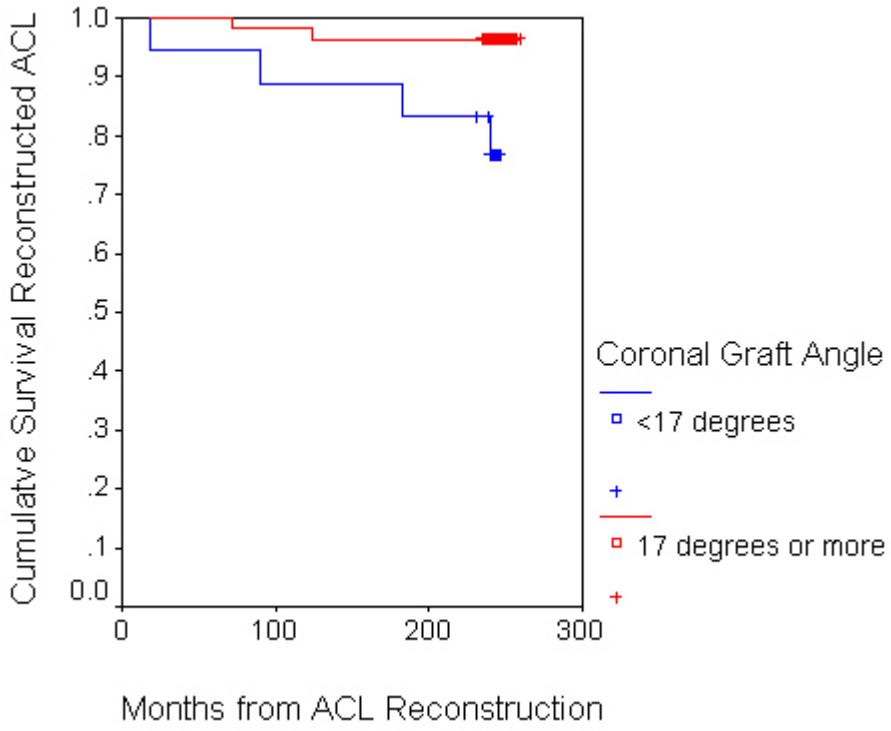
588 **Figure 7:** Kaplan Meier survival of the reconstructed ACL according to coronal graft angle.



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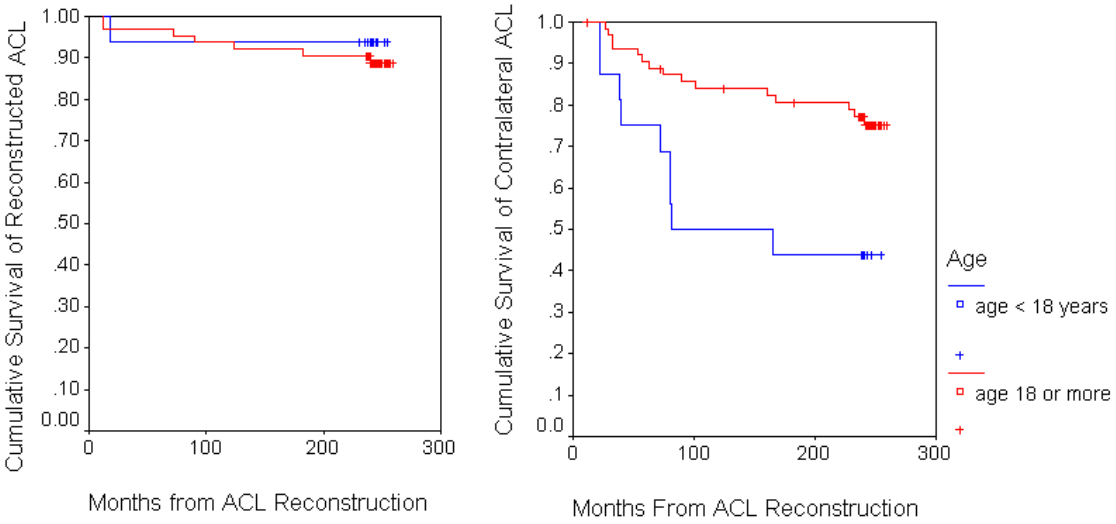
591 **Figure 8:** Cumulative survival of the ACL Graft (left) and contralateral ACL (right)

592 according to age



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TABLES

Table 1: Further Surgery over 15 years

# of Patients	Surgery to Index Knee	Months Post-op	# of Patients	Surgery to Contralateral Knee	Months Post-op
6	Revision ACL reconstruction*	12, 18, 76, 91, 126, 182	**25**	Contralateral ACL reconstruction*	Mean 82 (range 22-165)
9	Partial meniscectomy	14, 18, 62, 69, 99, 99, 204, 220, 228	**4**	Contralateral partial meniscectomy	44, 72, 96, 99
2	Arthroscopic debridement of Cyclops lesion	6, 242			
1	Arthroscopic arthrolysis	3			
1	Excision of patellar tendon cyst	24			
1	Arthroscopic chondroplasty	21			
1	Removal of tibial screw	87			

Table 2: Results of the 8 patients who had an ACL graft rupture. All 8 patients completed subjective review, 6 attended for clinical review.

	No of patients (%)
Proceeded to revision ACL reconstruction	6/8 (75%)
Effusion	1/6 (17%)
IKDC Score Mean (Range) N=8	84 (66-93)
IKDC Ligament Grade A	4/6 (67%)
IKDC ROM Grade A	4/6 (67%)
IKDC Overall Grade A	2/6 (33%)
Grade B	2/6 (33%)
Grade C	2/6 (33%)
Strenuous or Very Strenuous Activity at 20 years	2/8 (25%)
IKDC Radiological	
Grade A	2/7 (29%)
Grade B	2/7 (29%)
Grade C	3/7 (42%)
Grade D	0

605 **Table 3:** Comparison of female and male outcomes at 20 years

	Female	Male	Sig
No of subjects	42	38	
ACL graft rupture (%)	2%	16%	0.03
Contralateral ACL (%)	26%	35%	0.34
Subjective review no of subjects	37	35	
Mean IKDC Subjective Score (standard deviation)	83 (16)	90 (13)	0.03
Participating in strenuous or very strenuous activity at 20 yrs (%)	35%	66%	0.009
Pain with very strenuous activity at 20 years (%)	57%	20%	0.02
Objective review no of subjects	22	22	
IKDC Ligament Grade Normal (%)	96%	68%	0.03
Overall IKDC Grade Normal (%)	86%	55%	0.05
Radiological Grade Normal (%)	39%	40%	0.31

606

607 **Table 4: Summary of IKDC Clinical Examination at 20 years**

Summary of Clinical Examination at 20 years (n=44)	Grade A Normal	Grade B Nearly Normal	Grade C Abnormal	Grade D Severely Abnormal
Effusion	40 (90%)	4 (10%)		
Lachman	37 (84%)	7 (16%)		
Pivot Shift	42 (95%)	2 (5%)		
KT1000	38 (86%)	6 (14%)		
IKDC Ligament	37 (84%)	7 (16%)		
IKDC ROM	38 (86%)	4 (9%)	2 (5%)	
IKDC Overall	31 (70%)	11 (25%)	2 (5%)	
Single Legged Hop *not performed by 2 patients	35 (83%)	7 (17%)		

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609 **Table 5: Summary of IKDC Radiographic Examination at 20 years**

Summary of Radiographic Examination at 20 years (n=61)	Grade A Normal	Grade B Nearly Normal	Grade C Abnormal	Grade D Severely Abnormal
Medial Tibiofemoral	29 (48%)	23 (38%)	9 (15%)	
Lateral Tibiofemoral	51 (83%)	9 (15%)	1 (2%)	
Patellofemoral	42 (69%)	11 (18%)	8 (13%)	
Overall	24 (39%)	25 (41%)	12 (20%)	

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612 Table 6: Comparison of the parameters of tunnel placement between patients with
613 ruptured and those with intact grafts at 20 years

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	Intact ACL graft	Ruptured ACL graft	p-value
Number of patients (n)	78	7	
Mean (sd) tunnel placement			
Sagittal femoral (%)	85 (8)	78 (10)	0.05
Sagittal tibial (%)	41 (9)	36 (5)	0.20
Mean (sd) coronal graft inclination (°)	19.7 (4)	16.2 (4)	0.05