A total of 90 patients with an isolated rupture of the anterior cruciate ligament (ACL) had a reconstruction using the ipsilateral patellar tendon secured with round-headed cannulated interference screws. Annual review for five years showed three failures of the graft (two traumatic and one atraumatic); none occurred after two years. Ten patients sustained a rupture of the contralateral ACL. At five years, 69% of those with surviving grafts continued to participate in moderate to strenuous activity. Using the International Knee Documentation Committee assessment, 90% reported their knee as being normal or nearly normal and had a median Lysholm knee score of 96 (64 to 100). Most patients (98%) had a pivot shift of grade 0 with the remaining 2% being grade 1; 90% of the group had a Lachman test of grade 0. The incidence of subsequent meniscectomy was similar in the reconstructed joint to that in the contralateral knee. Radiological examination was normal in 63 of 65 patients. Our study supports the view that reconstruction of the ACL is a reliable technique allowing full rehabilitation of the previously injured knee. In the presence of normal menisci there is a low incidence of osteoarthritic change despite continued participation in sporting activity.

Received 14 September 1999; Accepted after revision 3 March 2000

Rupture of the anterior cruciate ligament (ACL) may lead to instability of the knee, subsequent meniscal injury and inability to carry out sporting activity at a high level. Persistent instability of the knee may result in high shear and compressive forces across the joint. The uniform distribution of such forces is dependent on the presence of intact menisci. Rupture of the ACL may lead to degenerative changes when associated with meniscal damage. Previous studies of endoscopic reconstruction of the ACL with the patellar tendon have shown an incidence of osteoarthritic change of up to 50% at a follow-up of seven years. There is, however, some debate as to whether early reconstruction may limit such episodes of instability and its concomitant osteoarthritic changes, or whether surgery should be reserved for those patients who have symptoms of instability despite conservative management.

Surgical reconstruction may involve both intra- and/or extra-articular approaches. The former include the use of autograft, allograft or synthetic material. Such procedures are increasingly being carried out endoscopically. Extra-articular reconstruction commonly requires open surgery and the use of a band of tensor fascia lata to augment anterolateral rotatory stability. Proponents of combined procedures have expressed concern about the long-term results of an isolated extra-articular reconstruction. The long-term results of open isolated extra-articular reconstruction have been poor, with a high incidence of laxity and the need for further surgery. Most surgeons use an isolated endoscopic intra-articular reconstruction since the additional benefit of an open extra-articular augmentation is unproven and the short-term results of intra-articular reconstruction appear to be satisfactory.

Assessment of the outcome of a technique of ACL reconstruction is hampered by the compounding effects of mixed patient selection, associated ligamentous injuries, chondral damage, meniscal injury and short-term follow-up. The indications for and timing of reconstructive surgery remain uncertain. We present the results of a five-year prospective study using a single technique. We have attempted to minimise the influence of extraneous variables by careful selection of patients. In particular, exclusion of those with significant meniscal damage and chondral injury has allowed us specifically to evaluate the medium-term natural history of endoscopic reconstruction of the ACL using an autogenous graft of the middle third of the ipsilateral patellar tendon.
Patients and Methods

Between January 1993 and April 1994, 333 patients who had reconstruction of the ACL were evaluated prospectively. The indication for operation was symptomatic instability secondary to rupture of the ACL confirmed by clinical examination. These patients were considered at high risk of further injury due to the degree of laxity and the desired level of activity. All had physiotherapy before surgery. In order to minimise the development of arthrofibrosis reconstruction was carried out only after the patient had regained 90° of flexion with minimal effusion or discomfort. We selected 90 patients for this study excluding those with other associated ligamentous injury requiring reconstruction, chondral damage noted at the time of operation, previous meniscectomy or excision of more than one-third of one meniscus at the time of reconstruction, an abnormal radiograph of the knee, pending compensation or an abnormal contralateral knee identified from the history or on clinical examination.

There were 48 men (53%) and 42 women (47%). The mean age at reconstruction was 25 years (13 to 42). The left side was involved in 35 patients (39%) and the right in 55 (61%). The ACL was reconstructed within three weeks of injury in three patients (3%), between three and 12 weeks in 64 (71%) and after 12 weeks in 23 (26%). The median preoperative Lysholm score was 64 (6 to 95). All patients had a Lachman test of grade 1 to 2. A total of 84 (93%) had a positive pivot-shift test. In the remaining six (7%), lack of full extension prevented adequate assessment. At arthroscopy the site of rupture of the ACL was noted to be midsubstance in 70 patients (78%), proximal in 14 (16%), indeterminate in two (2%) and previously excised in four (4%).

The principal causes of injury were soccer (21%), rugby (20%), netball (19%), touch football (18%), ski-ing (11%) and other sport (11%). The mechanism of injury was documented as pivoting in 28%, twisting in 20%, jumping in 18%, a tackle in 14%, a fall in 12% and other in 8%. The collateral ligaments were clinically normal in 87 patients. Three patients with an acute injury had laxity of the medial collateral ligament of grade 2; all were successfully treated by a preoperative brace. The state of the menisci at the time of surgery in this group has been previously described since this work is an extension of that study.

Operative technique. All procedures were carried out by the senior author (LAP) using a 7 × 25 mm round-headed cannulated interference (RCI) fit screw (Smith and Nephew Acufex, Mansfield, Massachusetts). No supplementary fixation was used. The technique has previously been reported in detail. Under general anaesthesia, a single dose of intravenous cephalosporin was administered. The limb was exsanguinated using an Esmarch bandage before inflation of a high thigh tourniquet. A diagnostic arthroscopy was undertaken and suturing of appropriate meniscal lesions carried out using an inside-out technique with postero-medial or posterolateral incisions. A patellar tendon graft with trapezoidal bone block 20 to 25 mm long was taken using two separate longitudinal incisions placed at the distal aspect of the patella and just medial to the tibial tubercle. Only a soft-tissue clearance of the notch was carried out. The femoral hole was drilled through the anteromedial portal at the 11 (right) or 1 (left) o’clock position and 5 mm anterior to the attachment of the posterior capsule. The tibial recipient site was prepared. The length of the tibial tunnel was determined by the length of the graft so that the tibial bone block was within 1 cm of the external aperture of the tunnel. Both ends of the bone-patellar tendon-bone complex were secured using an RCI screw with the femoral end being secured endoscopically first. Full extension of the knee was ensured before final locking of the tibial screw. Stability was checked using the anterior drawer and Lachman tests. The mean tourniquet time was 69 minutes (40 to 114). Patients were in hospital for a mean of 1.5 days (1 to 3).

Immediate weight-bearing with crutches was allowed according to comfort. A rehabilitation programme was started on the first postoperative day with closed chain exercises, leading to proprioceptive and sports training after three to six months. Patients were discouraged from returning to competitive sport involving jumping, pivoting or sidestepping until six to nine months after reconstruction and then only after formal clinical evaluation.

All patients were assessed by an independent examiner before operation and at two and six weeks and at three, six and 12 months after surgery, and annually thereafter. The symptoms and signs of knee function were assessed to complete the International Knee Documentation Committee (IKDC) knee grade. The patients were graded as normal (A), nearly normal (B), abnormal (C) or severely abnormal (D). The final grade is determined by the worst score in any of the four principal categories: subjective assessment, symptoms, range of movement and ligament examination. The IKDC grades activity into three categories. These are the level of activity (1, strenuous; 2, moderate; 3, light; and 4, sedentary), the level of competition (competitive, vigorous recreational, light recreational, activities of daily living) and the total number of hours spent each year at the highest level of activity. The Lysholm knee score is designed to evaluate specific symptoms relating to knee function including limp, support, locking, instability, pain, swelling, stair-climbing and squatting. It was completed by a self-questionnaire, as this has been shown to give reliable results. Ligament testing was carried out by means of the Lachman, anterior drawer and pivot-shift tests. Instrumented laxity testing was undertaken using the KT1000 arthrometer (MEDmetric Corporation, San Diego, California) recording side-to-side differences in displacement at 9.1 kg and on maximum manual testing. Thigh atrophy was measured as the difference between the two sides at a point 10 cm above the superior pole of the patella. Fixed flexion was measured with the patient supine.
using a goniometer. The relevant landmarks used were the lateral malleolus, the lateral joint line of the knee and the greater trochanter. In cases of minimal or no fixed flexion deformity, patients were examined prone with the legs dependent over the end of the bed allowing easy assessment of active and passive extension. Pain on kneeling on a standard rigid carpet surface was recorded for site and severity using an analogue score from 0 (no pain) to ten (most severe pain). Before surgery, and at two and five years, weight-bearing anteroposterior, posteroanterior, 30° flexion, lateral and tunnel view radiographs were taken. Each set of films was interpreted on two separate occasions by two independent surgeons. Discrepancies in reporting were examined by a third surgeon to obtain agreement. Statistical analysis. This was undertaken using the SPSS version 7.5 for Windows. For interval and ordinal data, comparisons between the results at two and five years were made using the Wilcoxon signed-rank test. For nominal data, comparisons were made using McNemar’s test.

Results

Of the 90 patients, we reviewed 82 at one year after surgery. The corresponding numbers of patients reviewed after two, three, four and five years were 77, 72, 68 and 80, respectively. During this period, three patients had a rupture of the ACL reconstruction, making them ineligible for inclusion in the study. All three subsequently had revision procedures. Of the remaining 87 patients complete data were obtained in 80 (94%) at five years. Two patients were lost to follow-up. Of the other five, one had been assessed clinically at four years, three had been seen at three years and one at two years. Three had been contacted by telephone at the time of the five-year review to exclude further injury and/or surgery. The results of clinical assessments therefore refer only to those patients with intact ACL grafts at the time of each annual review. During the period of review, ten patients sustained a rupture of the ACL in the contralateral knee. Their results have been included except for instrumented testing which assumes an intact contralateral knee for comparison.

Figure 1 gives the breakdown of the categories of subjective assessment at the time of each review. After injury and before surgery 3% of patients graded their knee function as normal. This rose to 73% at two years and 74% at five years (p = 0.84). Beyond two years after surgery, 95% or more of the patients graded their knee as normal or nearly normal.

The highest level of activity at which a patient could function without significant pain, swelling or giving-way was recorded at two and five years (Table I). Over 90% of patients were able to undertake strenuous or moderate activities after reconstruction without these problems on both reviews.

When range of movement was assessed before surgery, 18 patients (20%) had an extension deficit of greater than 5°. We found an increase in the number of patients with an extension deficit of between 0° and 5° with the passage of time (Table II). At 12 months, 7% of patients had a measurable extension deficit and this rose to 31% at five years (p = 0.001). A flexion deficit of greater than 5° was found in 51 patients (57%) before surgery but in only two was found in two and one at two and five years, respectively.

Lachman and pivot-shift tests. Before operation, all patients had a Lachman test of grade 1 to 2. At two years, in 81% of 77 patients it was grade 0. This percentage rose progressively with time so that at the five-year review, 90% of patients had a grade-0 test (Table II). There was no significant difference between years two and five (p = 0.08). Of the 15 patients (19%) with a grade-1 Lachman test at two years, 14 were available for review at five years; nine had a grade-0 test and three a fixed flexion deformity of 5° or less. Before operation, the pivot-shift test was positive in all patients who had full extension. After surgery, more than 90% of patients had a grade-0 pivot test at each review (Table II). This percentage increased slightly, so that 98% had a grade-0 pivot shift at

![Fig. 1](image_url)

The patients’ subjective assessment of their knees before surgery and at each review.
five years (p = 0.06 for comparison of year 2 with year 5). KT1000 instrumented testing was carried out in 70 patients at five years. Ten patients who had sustained a contralateral rupture of the ACL were excluded from this analysis. Side-to-side differences in knee stability were assessed at both 9.1 kg of anterior displacement and on maximum manual testing (Table II). As expected, the two were similar (Kendall’s τc = 0.417). At each review, more than 79% had less than 3 mm side-to-side difference on KT1000 assessment.

IKDC grading. There is recent evidence that the final IKDC grade is reliable compared with other rating scales.13 We grouped the normal or nearly normal together, and the percentage in this category is shown in Table II for the review periods after surgery. Over 85% of patients were considered as A or B at each period. Table III gives the details of those patients with an IKDC score of C or D.

Tenderness at the graft site. Patients were asked to report the presence and severity of tenderness, irritation or paraesthesiae at the graft site. At two years, 56% of patients reported no symptoms, 34% had mild and 9% moderate symptoms. Only one had severe tenderness and irritation at the graft site. At five years, these percentages were virtually unchanged. The patient with discomfort at the graft site at two years continued to report severe tenderness at five years, despite a variety of conservative measures.

Radiological assessment. The medial, lateral and patellofemoral compartments were reviewed for narrowing of the joint space. Using the IKDC system for grading (A, normal; B, > 4 mm of joint space; C, 2 to 4 mm of joint space;
D, < 2 mm of joint space), at the two-year review, only one of 67 radiographs was abnormal (grade B). At the five-year review, radiographs were available for 65 patients; 63 (97%) were graded A and there were grade-B changes in the medial compartment in two patients (3%).

**Lysholm knee score.** The highest obtainable score is 100. The results, given as the median and interquartile range, are shown in Figure 2. The median score after injury before surgery was 64 (6 to 95). At two years the median score was 95 (26 to 100) and at five years it was 96 (64 to 100).

**Thigh atrophy.** At two years, 95% of patients had thigh wasting of <1 cm, 4% had 1 to 2 cm and one patient had 3 cm. At five years 70 patients (87%) had wasting of <1 cm, seven patients (9%) had a discrepancy of 1 to 2 cm and three (4%) had 3 cm of thigh atrophy. Table II shows those patients with thigh atrophy of <1 cm during the review period. This percentage remained consistently above 80% for each period with no significant difference between years two and five (p = 0.13).

**Kneeling test.** At the two-year review, 69% of patients reported no pain on kneeling. This percentage fell to 56% at five-years with 16% reporting pain localised to the patellar tendon at two years and 25% with pain at this site after five years (p = 0.33).

**Level of activity.** Before injury, 99% of patients were involved in level 1 or 2 activities. Table II shows that this fell from 84% at two years to 69% at the five-year review (p = 0.02 for comparison between years two and five). We found a gradual decrease in the percentage of patients who were participating in competitive or vigorous activities (Table II). This fell from 86% after two years to 67% at four and 66% at five years (significant difference between years two and five, p = 0.001). The total number of hours spent each year at the highest level of activity is shown in Figure 3. This takes no account of the level of competitiveness and must be viewed in conjunction with Table II. Figure 3 demonstrates the median number of hours spent each year at the highest level of activity achieved for each patient. It has previously been reported that at two years significantly fewer women (54%) than men (36%) had returned to their preinjury level of activity in all three categories. At five years, these percentages had risen to 72% of women and 59% of men, respectively. No significant gender difference was identified at the final review (p = 0.21). At two years, 66% of patients had decreased their level of activity in no or only one category compared with before injury and this remained similar at 60% at the five-year review. Of the 32 patients with a decrease in the level of activity of more than one category, only eight stated that this was a result of the knee injury.

**Late complications and further intervention.** At the five-year annual review three patients were known to have sustained a further rupture. There was one case of atraumatic rupture at 11 months. Ten patients had a traumatic contralateral rupture of the ACL at a median time of 31 months (23 to 57). One developed ipsilateral patellar tendonitis, which was managed conservatively by oral analgesia and a further rehabilitation programme. A further patient required excision of a cyst of the patellar tendon at 24 months, which resulted in the elimination of anterior symptoms. One patient required support with a brace for six weeks for a further isolated injury to the medial collateral ligament, 32 months after ACL reconstruction. Two patients required arthroscopic debridement for a cyclops lesion at six and 24 months after surgery, and two needed partial ipsilateral meniscectomy, one medial and one lateral, within two years of reconstruction. One patient had an arthroscopic arthrolysis at three months and another arthroscopic chondroplasty at 21 months.

**Discussion**

Reconstruction of the ACL aims to restore normal stability to the knee and allow return to the level of function before injury. Restoration of normal kinematics may minimise the abnormal shear forces at the femorotibial interface. It is believed that the recurrent episodes of instability which occur after rupture of the ACL are often associated with meniscal damage and cause degenerative changes.
scopic examination of ACL-deficient knees in which reconstruction has been delayed, has identified high levels of meniscal injury and chondral damage and these joints have a high incidence of osteoarthritic change after reconstructive surgery. In our study, high-demand patients had early reconstruction of the ACL in an attempt to minimise subsequent meniscal injury, articular damage and osteoarthritis, since such individuals have previously been shown to be at high risk of the late development of functional impairment, secondary meniscal tears and arthritis. All patients had sustained the injury while playing sport and were a select group with no significant associated ligamentous, meniscal, or chondral injuries. As such our study documents the natural history of surgical reconstruction for isolated rupture of the ACL and is a baseline for the assessment of other reconstructive procedures and more complex injuries involving this ligament.

The timing of surgery after injury remains controversial but we consider this to be crucial in determining outcome. In our series, operation was carried out as soon as the knee had progressed from the acute phase of injury to a less irritable state. With resorption of the intra-articular haemorrhage and reduction of inflammation the reconstruction is easier to carry out. To this end, we started physiotherapy before surgery and most patients (97%) had their operation more than three weeks after injury. While some authors have suggested delaying surgery to at least four weeks in an attempt to minimise the development of a flexion contracture, a more recent controlled prospective study has suggested delaying surgery to at least four weeks in an attempt to minimise the development of a flexion contracture and the development of a high incidence of osteoarthritic change after reconstructive surgery. In our study, a contralateral rupture of the ACL was seen in 11% of patients, which is less than that reported in some similar series. The pathogenesis of atraumatic rupture may be related to non-isometric placement of the graft with gradual plastic deformation at full extension. One patient in our series suffered an atraumatic rupture. We identified an overall rate of rupture of the graft of 3%. During the same period, a contralateral rupture of the ACL was seen in 11%. We feel that this is due to sampling error, but reflects the level of activity of these patients. We have carried out a recent study of 610 patients who had had a similar reconstruction, but did not fulfil the inclusion criteria for this study. No significant difference was found between the rate of ipsilateral (6.0%) and contralateral (5.7%) rupture of the ACL over a five-year period.

The one-legged hop test has previously been shown to be a reliable indicator of knee function. Daniel et al have reported a left/right one-legged hop-for-distance ratio of 0.9 or more in 95% of 100 normal subjects. We found that 89% of our patients had a hop-for-distance ratio of 0.9 at five years. These findings are in keeping with previous reports. Patellofemoral discomfort after reconstruction of the ACL remains an unresolved problem. Several causes have been proposed. These include a limited range of movement before surgery, concurrent chondromalacia, poor rehabilitation, pain at the site of graft harvest, the presence of a fixed flexion contracture and the development of patella baja subsequent to fibrosis of the patellar tendon. We found a low incidence (8%) of patellofemoral crepitus on clinical examination. This is less than that reported using a similar two-incision technique in which, at the five-year follow-up, 45% of 97 patients were found to have patellofemoral crepitus. At five years, 91% of our group reported mild or no pain related to the harvest site. Pain on kneeling, however, remained a persistent problem, with...
44% of patients describing some discomfort on kneeling five years after surgery. Preoperative counselling should include a discussion of this complication.

The fundamental objective of reconstruction of the ACL is the restoration of stability of the knee. Secure fixation of the graft allows for early rehabilitation. Proponents of combined intra- and extra-articular approaches to reconstruction of the ACL claim that these procedures give better long-term results than intra-articular procedures alone. Such an argument presumes that isolated intra-articular grafts inevitably become lax or are prone to re-injury. At five years, 90% of 80 patients had a grade-0 Lachman test and 98% had a negative pivot-shift test. Instrumented testing confirmed that more than 80% had a persistent side-to-side manual maximum difference of less than 3 mm at each period up to five years after surgery. Similar results were recorded for anterior displacement at 9.1 kg. Using a patellar tendon graft with a MacIntosh extra-articular augmentation, Ruckemann reported a positive Lachman test in over 50% of patients at the three-year review. Anderson, Snyder and Lipscomb, using hamstring tendons through an open approach in combination with a lateral tenodesis with the iliotibial band, found that 19% had a Lachman grade of at least 1+ at six years. These results presumably reflect non-anatomical placement of the intra-articular graft. We feel that there is no indication for the added surgical morbidity and exposure required for such augmentation procedures.

An accelerated rate of degenerative change has been found in the knees of patients with rupture of the ACL. Other series also confirm a higher rate of such changes in patients who have had reconstruction. These results may have been biased by the influence of concurrent meniscal and chondral damage in the study groups. There appears to be a correlation between delay in reconstruction and the frequency of such injury. Isolated meniscal lesions in themselves may predispose to arthritic change. We presume that no damage occurred to the joint surfaces during the surgical procedure as a notchplasty was not undertaken. Early rehabilitation with restoration of movement and full weight-bearing immediately after operation minimised local inflammation and allowed early restoration of the normal biomechanics of the knee. It is accepted that a minimum five-year review is required to identify radiological and clinical evidence of degenerative change. In our series only two out of 65 patients showed grade-B changes on the radiographs. In both, the abnormality was a spur with early formation of osteophyte rather than loss of joint space, and was seen only in the medial compartment. These results are encouraging, and are substantially better than those reported for both conservatively-managed ACL-deficient knees and unselected ACL reconstructions. We acknowledge that visual inspection at the time of the initial surgery may not enable the surgeon to assess completely the state of the chondral surfaces. Newer imaging modalities may define more accurately the presence and extent of bony injury in the absence of abnormalities of the articular surface. The relevance of these findings to the development of arthritic change remains undetermined.

We noted an increase in the percentage of patients with a fixed flexion deformity beyond three years after operation. Over the same period there was a concurrent increase in the percentage of patients with a grade-0 Lachman test and a negative pivot-shift test. These findings may be related and could reflect the first clinical manifestations of degenerative change in this group. The use of bone-patellar-bone autograft has been shown to be associated with a small incidence of arthrofibrosis and shortening of the patellar tendon. Aglietti et al found that 26% of his patients had at least an extension deficit of 3° at a mean follow-up of seven years after reconstruction. We are unaware of any other prospective longitudinal study of reconstruction with patellar tendon autograft which may support this finding.

Endoscopic reconstruction of the ACL using an ipsilateral patellar tendon graft fixed with 7 \times 25 \text{ mm} RCI titanium screws affords lasting stability, protection of the meniscus and possibly against degenerative change during the first five years after surgery. We have found that the maintenance of high levels of sporting activity may lead to re-injury. Worryingly, we have noted an increased incidence of a fixed flexion deformity with the passage of time. This report has defined the natural history of surgical reconstruction for ACL deficiency without the compounding effects of recurrent injuries in a group of patients which remains the subject of an ongoing study.

We wish to acknowledge the kind assistance of Peter Cooper, Head of Statistics, Smith and Nephew, York, UK for his advice on statistical analysis.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References


