



Endoscopic reconstruction for isolated anterior cruciate ligament rupture

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We treated 90 patients with an isolated injury to the anterior cruciate ligament (ACL) by reconstruction using a patellar tendon autograft and interference screw fixation.

Of these, 82 (91%) were available for review at 24 months. Two grafts and two contralateral ACLs had ruptured during sport and there was one case of atraumatic graft resorption. Using the assessment of the International Knee Documentation Committee (IKDC), 86% of the remaining patients were normal or nearly normal. The median Lysholm knee score was 95/100 and 84% of patients were participating in moderate to strenuous activity. All had grade-0 or grade-1 Lachman, pivot-shift and anterior-drawer tests. Measurement with the KT1000 arthrometer gave a side-to-side difference of <3 mm of anterior tibial displacement in 90%. Sixty-six radiographs were IKDC grade A and one was grade B. Pain on kneeling was present in 31% and graft site pain in 44%.

At 24 months after operation all patients had excellent knee stability, a high rate of return to sport and minimal radiological evidence of degenerative change. Our series therefore represents a basis for comparison of results using other techniques and after more severe injuries.

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In the past, loss of or damage to the anterior cruciate ligament (ACL) was considered to be of little importance to the long-term function of the knee.¹ Several studies have shown, however, that instability after rupture of the ACL may lead to recurrent episodes of giving way,² an increased risk of meniscal injury^{2,3} and premature degenerative changes.³⁻⁶

Many different techniques have been used to restore stability to the ACL-deficient knee, but several have produced poor long-term results. These include direct repair,⁷ extra-articular procedures^{8,9} and intra-articular prostheses.¹⁰⁻¹²

The two most commonly used autografts for intra-articular reconstruction of the ACL are the central one-third of the patellar tendon (PT) and the combined semitendinous and gracilis tendons (STG).^{13,14} The PT autograft is secured by interference screw fixation of the bone blocks and gives enough stability^{15,16} to allow intensive rehabilitation.¹⁷ It is the current 'gold standard' for ACL reconstruction.¹⁴

A PT autograft may be inserted by either an open technique, a mini-arthrotomy with arthroscopic assistance or by an endoscopic technique. Whichever procedure is used, the outcome after reconstruction may be affected by associated damage to the collateral ligaments, the menisci and the chondral surfaces.^{18,19} These injuries may be sustained at the time of the original injury or during subsequent episodes of giving way.

Our aim was to assess the outcome following ACL reconstruction after eliminating the confounding effect of other pathology in addition to the ACL injury.

Patients and Methods

Between January 1993 and April 1994, we evaluated prospectively 333 patients in a tertiary referral centre who were having ACL reconstruction. We used the following exclusion criteria: 1) any associated ligament injury requiring surgery; 2) evidence of chondral damage or degeneration; 3) previous meniscectomy; 4) excision of more than one-third of one meniscus at the time of reconstruction; 5) an abnormal radiograph; 6) an abnormal contralateral knee; 7) those seeking compensation for their injury; and 8) those who did not wish to participate in a research programme. These exclusions left 90 patients in the study, 48 males and 42 females with a mean age of 25 years (13 to 42). The

Table 1. State of the 90 menisci at the time of ACL reconstruction

Meniscus	Medial	Lateral
Intact	73	56
Healed	6	7
Untreated	6	19
Sutured	5	2
Partly excised	0	6

main causes of injury were soccer (19), rugby (18), netball (17), touch rugby (16), ski-ing (10) and other activities (10). The principal mechanisms of injury were pivoting/side-stepping (25), twisting (15), landing from a jump (13) and being tackled (12).

The ACL was reconstructed in the acute phase (< 3 weeks from injury) in three patients (3%), in the subacute phase (3 to 12 weeks from injury) in 64 (71%) and in the chronic phase (> 12 weeks from injury) in 23 (26%). All patients had a preoperative Lachman test of grade 1 to grade 2 and 93.5% had a positive pivot shift; the remainder had locked knees and a pivot shift could not be performed.

Table 1 shows the state of the menisci at the time of reconstruction. 'Healed' menisci were those deemed to have been damaged at the time of rupture of the ACL and had subsequently healed; 'untreated' menisci had small tears that were stable to probing; and 'sutured' menisci had longitudinal red-on-red or red-on-white tears which required stabilisation.

Operative technique. All operations were done by the senior author (LP) under general anaesthesia and tourniquet. A diagnostic arthroscopy was performed using high anterolateral and low anteromedial portals. The notch was cleared and the stump of the old ACL removed. We performed suturing of any meniscal lesions using an inside-out technique with posteromedial or posterolateral incisions for capsular exposure. We used a double-barrelled suture passer (Smith and Nephew Endoscopy, Mansfield, Massachusetts) to space 2.0 PDS sutures every 5 mm along the length of the longitudinal tear. They were tied over the capsule before ACL reconstruction.

We used two longitudinal incisions of 2 cm for taking the graft. The upper incision was placed at the distal aspect of the patella and the lower just medial to the tibial tubercle. A trapezoidal-shaped bone block 25 × 9 mm was removed from the patella. The patellar tendon was incised subcutaneously using a Smillie knife and a tibial bone block 30 × 9 mm was removed.

An arthroscope was then inserted through a central portal in the infrapatellar incision. This gave a deeper view of the notch and allowed the placement of the femoral tunnel. Clearance of soft tissue from the notch gave a view of the position of the femoral tunnel 5 mm anterior to the true posterior capsular insertion and at the 11 o'clock (right) or 1 o'clock (left) position with respect to the apex of the notch.

We used a bone awl to begin the femoral tunnel and with the knee fully flexed continued with a 4.5 mm drill bit inserted from the anteromedial portal and aimed approximately 30° lateral and 30° anterior to the femoral axis. A 2.4 mm Beath pin was placed in the drill hole followed by a 9 mm cannulated drill inserted to the same depth as the length of the patellar bone block.

The tibial tunnel was created using a drill guide inserted through the anteromedial portal. The tip of the guide was placed within the remnants of the stump of the ACL at a position one-third of the distance from the medial end of a line joining the anterior horn of the lateral meniscus and the medial tibial spine. A 4.5 mm drill hole was created into which a 2.4 mm Beath pin was inserted. The final 9 mm tunnel was formed using a cannulated drill. The length of the tibial tunnel was usually 45 to 50 mm. Debris including any remaining stump of the ACL at the aperture of the tibial tunnel was removed to avoid impingement when the knee was fully extended ('a cyclops lesion').

The patellar tendon autograft was then passed into the knee using a pull-through suture and the bone blocks positioned in their tunnels and secured. The patellar bone block in the femoral tunnel was placed with the cancellous side facing anteroinferiorly. With the knee fully flexed an RCI screw (Smith and Nephew Endoscopy) was inserted via the anteromedial portal into the interface between the bony tunnel and the cancellous area of the bone block to allow parallel placement of the interference screw with the bone block. Firm traction was then applied to the tibial bone block while the knee was taken through a full range of movement to pretension the graft and to observe full extension without impingement. An RCI screw was inserted parallel and posterior to the tibial bone block and initially advanced two to three turns while the knee was flexed. When a firm grip was obtained the leg was straightened to ensure full extension and the screw was fully seated. Stability was checked by the Lachman and anterior-drawer tests.

The knee was then thoroughly irrigated. 10 ml of 0.25% marcaine were instilled into the joint and around the portals, the wound was closed and dressings applied. The median tourniquet time was 1 hour and 8 minutes (40 min to 1 hour 54 min).

Patients began weight-bearing on crutches immediately for a median of ten days (2 to 21). They were given simple analgesics for pain control and daily physiotherapy to reduce postoperative swelling and to allow active exercises aiming for full extension by 14 days. The usual clinical follow-up included review at 10 to 14 days for wound inspection and suture removal. The patients were seen at six weeks, six months and then yearly. The intensive rehabilitation programme included closed-chain exercises and an emphasis on proprioceptive training. At six weeks, patients began jogging in straight lines, swimming and using a bicycle. From 12 weeks general strengthening exercises were continued with agility work and sporting

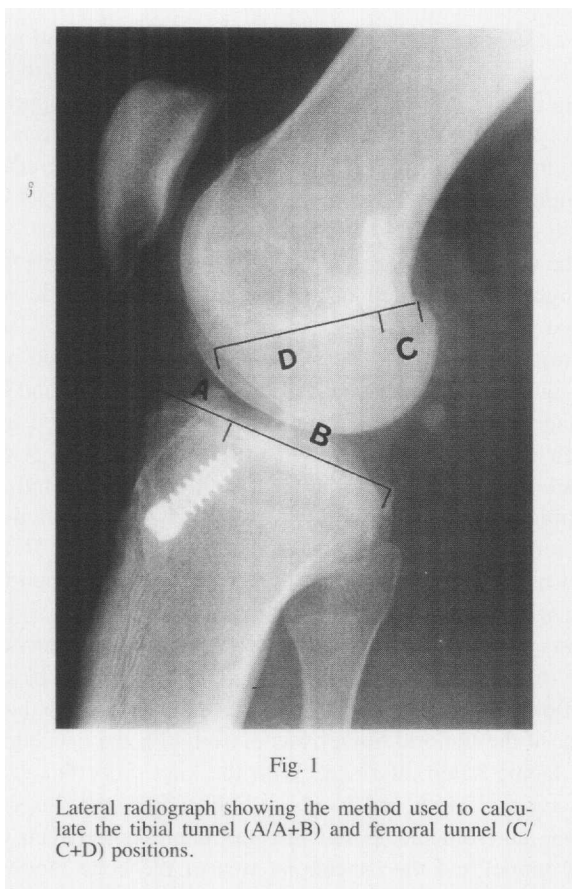


Fig. 1

Lateral radiograph showing the method used to calculate the tibial tunnel ($A/A+B$) and femoral tunnel ($C/C+D$) positions.

activities encouraged. Return to competitive sport involving jumping, pivoting or sidestepping was prohibited until nine months after the reconstruction, but with variable patient compliance.

Follow-up. All patients were assessed preoperatively and at 12 and 24 months by one examiner using the evaluation of the International Knee Documentation Committee (IKDC).²⁰ Ligament stability was measured by the Lachman,²¹ anterior-drawer and pivot-shift tests.²² The Lachman and anterior-drawer tests were graded as 0 (< 3 mm laxity), 1 (3 to 5 mm laxity) and 2 (> 5 mm laxity) and the pivot-shift test as 0 (negative), 1 (glide), 2 (clunk) and 3 (gross). Instrumented knee testing was performed using the KT1000 arthrometer (MEDmetric Corporation, San Diego, California) using a displacement force of 9.1 kg. Thigh atrophy was determined by measuring the difference in thigh circumference 10 cm above the superior pole of the patella and the degree and location of pain on kneeling were determined.

The level of sporting activity before injury and at 24

months after reconstruction was assessed using three criteria: 1) the category of sport according to the IKDC levels I to IV as strenuous (rugby, basketball), moderate (ski-ing, tennis, heavy manual labour), light (jogging) and sedentary; 2) the level of competition, i.e., competitive sport (CS), vigorous recreational (VR), light recreational (LR), and activities of daily living (ADL); and 3) an estimate of the time spent participating in the given sport as the number of hours per year.

Patients completed the Lysholm knee score²³ to document subjective symptoms. The placement of femoral and tibial tunnels was assessed on the lateral radiographs using the technique described by Jonsson et al.²⁴ The position of the tibial tunnel is described in relation to the tibial plateau ($A/(A+B)$; Fig. 1) expressed as a percentage and that of the femoral tunnel is taken as the centre of the femoral screw placed in relation to Blumensaat's line ($C/(C+D)$; Fig. 1).

Results

Of the 90 patients, eight were unwilling or unable to return for assessment. Six of these eight were stable at their (last) six-month review and two were stable at 12 months.

Two patients ruptured their graft playing soccer 11 and 18 months, respectively, after reconstruction. Two ruptured their contralateral ACL during sport at 23 and 24 months, respectively, after reconstruction. One graft failed without any history of trauma. The results of these five patients are reported but they are excluded from the evaluation leaving 77 patients for assessment.

IKDC evaluation

Subjective assessment. This was defined as four grades as follows: normal (A), nearly normal (B), abnormal (C) and severely abnormal (D). Before injury to the ACL, 76 patients (99%) considered their knee to have been grade A. Twenty-four months after reconstruction 73% were grade A, 22% were grade B, 4% were grade C and one was grade D.

Symptoms. Pain, swelling and giving way were graded at the highest activity level at which the patient would be able to function without significant symptoms. The absence of pain, swelling or giving way during strenuous activity is therefore graded as normal. Table II gives the results.

Range of movement. At 24 months, 74 patients (97%) had full extension or lacked $\leq 3^\circ$, and 2 (3%) were lacking 4 to 5° ; 76 (99%) had full flexion or lacked less than 5° at 24 months and one patient lacked 7° .

Ligament examination. Lachman and pivot-shift testing

Table I. State of the 90 menisci at the time of ACL reconstruction

Meniscus	Medial	Lateral
Intact	73	56
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Untreated	6	19
Sutured	5	2
Partly excised	0	6

Table III. Clinical and instrumented graft stability by percentage

Grade	Lachman		Pivot shift	Anterior drawer	KT1000*
	Preop	Postop			
0 (<3mm)	0	81	91	99	90
1 (3 to 5mm)	66	19	9	1	7
2 (>5mm)	36	0	0	0	3

* KT1000 assessment at 9.1 kg anterior displacement force

Table IV. Summary of patients with IKDC grade C or D

Case	Gender	Age (yr)	Timing of surgery*	IKDC				
				Overall grade	Subjective assessment	Symptoms	ROM†	Stability
1	M	25	SA	C	B	C	A	A
2	M	27	SA	C	C	B	A	A
3	M	23	SA	C	C	C	A	A
4	F	42	SA	C	C	B	A	B
5	F	31	C	C	C	C	A	A
6	M	24	SA	C	C	A	A	A
7	M	18	C	C	C	C	B	A
8	M	26	SA	D	C	D	A	A
9	F	41	SA	D	C	D	A	A
10	F	23	A	D	C	D	B	B
11	F	24	A	D	C	D	B	B

* A, acute; SA, subacute; C, chronic

† range of movement

showed all patients with laxity of grades 0 to 1. In 61 patients the difference in AP laxity between the injured and normal knee was also recorded using the KT1000 arthrometer and the results are given in Table III.

Compartment findings. Crepitus was assessed as the difference between the injured and normal knee. Five patients (6%) had mild and one had moderate crepitus. In the patellofemoral compartment mild crepitus was felt in the medial compartment of three (4%) and in the lateral compartment of one patient.

Graft-site tenderness. Over half (56%) of the patients did not have tenderness, irritation or numbness about the patellar tendon graft site. In 26 (34%) these symptoms were slight and in seven (9%) moderate. One patient had severe symptoms.

Radiological assessment. Radiographs included weight-bearing AP and 30° flexion AP views as well as lateral, tunnel and skyline views of the affected knee. All pre-operative radiographs were normal. In 67 patients at 24 months they were classified as IKDC grade A in 66 and grade B in one.

Functional tests. A total of 70 patients (91%) was able to hop 90% to 100% of the distance achieved using the uninjured leg. Four patients hopped 75% to 89% and two patients hopped 50% to 74%. One pregnant patient refused to perform the hop test.

Overall IKDC rating. The overall rating is determined from the lowest grade recorded in any of the four groups of subjective assessment, symptoms, range of movement and ligament stability. Of the 77 patients, 37 (48%) were graded as normal (A), 29 (38%) as nearly normal (B), 7 (9%) as abnormal (C) due to a low score in the subjective assess-

ment category, and 4 (5%) as severely abnormal (D), all due to pain. None of the poor results was due to poor range of movement or stability. Table IV gives details of those patients in grades C and D. There was no difference in the overall IKDC score or of the variables measured between patients who had reconstruction in the acute/subacute phase compared with those who had reconstruction in the chronic phase.

Thigh atrophy. At 12 months 66 patients (86%) showed wasting of the thigh circumference of the injured leg of 1 cm compared with the uninjured leg; 10 (13%) had wasting of 1 to 2 cm and one patient had 3 cm. By 24 months, 73 (95%) had wasting of ≤1 cm, 3 (4%) had 1 to 2 cm and one patient had 3 cm compared with the uninjured leg.

Kneel test. At 24 months 52 (68%) of patients had no pain on kneeling. In the remaining patients pain on kneeling was felt over the patellar tendon in 12 (16%), the general anterior aspect of the knee in 8 (11%), over the tibial tubercle in two patients, over the patella in two and over the lateral aspect of the knee in one.

Activity level. Before injury 94% of patients participated in IKDC level-I activities. At 24 months 84% were engaged in level I to II activities compared with 12 months when 73% participated in level I to II sport. Patients who were participating in level I to II activity at 24 months had a mean thigh atrophy which was significantly less than those involved in level III to IV activities (0.2 cm v 0.8 cm; Mann-Whitney U test, $p = 0.02$). Thirty-four patients dropped their activity level to some degree; 16 in all three categories assessed, ten in two categories and eight in one. Twenty-four patients reduced the number of hours/year

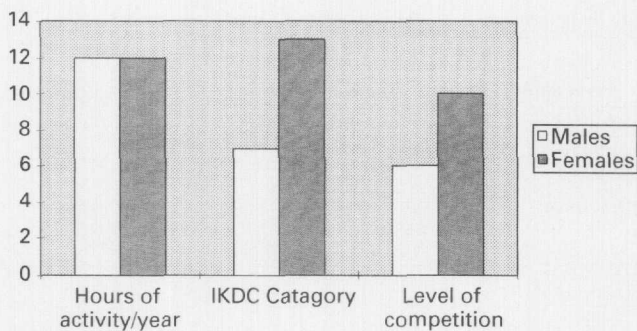


Fig. 2

Number of patients who reduced their activity level according to the three categories used for assessment.

spent playing sport, 20 played a less demanding sport and 16 reduced their level of competition (Fig. 2). There were significant differences between males and females in that 19 of 35 (54%) females compared with 15 of 42 (36%) males did not return to their preinjury activity level in one or more of the three categories assessed. The reconstructed knee was the reason given for the reduction in the activity in 8 of 19 females and 9 of 15 males.

Lysholm knee score. The preoperative Lysholm knee scores were poor, with a median of 61 (6 to 95), as would be expected after injury. The median Lysholm score at 12 months was 95 (70 to 100) and at 24 months 95 (26 to 100). The mean Lysholm score was 94 at 12 months and 93 at 24 months with 69 patients (90%) scoring good or excellent (≥ 84) at 24 months.

Tunnel positioning. The mean femoral tunnel position in relation to the posterior femoral cortex, expressed as a percentage of the total femoral depth along Blumensaat's line, was $23 \pm 5\%$. The mean tibial tunnel position from the anterior tibial cortex, expressed as a percentage of the total depth of the tibial plateau, was $41 \pm 4\%$. The positions of the three ruptured grafts were 20%, 14% and 40%, respectively for the femur and 46%, 49% and 40% for the tibia.

Complications and subsequent surgery. There were two superficial wound infections which resolved on treatment with oral antibiotics. One of these patients subsequently ruptured his graft playing soccer at 11 months. There were three late arthroscopies, one for arthrolysis and two for excision of cyclops lesions to allow full extension. There was one case of patellar tendonitis which required anti-inflammatory medication and a further rehabilitation programme for resolution. The patient who had contralateral ACL reconstruction at 24 months also had excision of a patellar tendon cyst at the same time.

Discussion

In our study, rupture of the ACL almost exclusively occurred at sport. Most patients were participating in regular competition of a level-I sport for an average of over 200 hours per year. Daniel and Fithian²⁵ suggested that the best

predictor of a patient requiring late surgery for ACL rupture was the number of hours of participating in level I to II sport which, taken in combination with the degree of knee laxity, could be used to help to decide which patients should have reconstructive surgery. Patients in a high-risk group who did not have reconstruction were estimated to have a 40% chance of requiring late meniscal or ACL surgery within five years of injury. These guidelines were used in selecting the cohort of 333 patients undergoing ACL reconstruction from which our study group was obtained.

The exclusion criteria were used in an attempt to produce a patient population with obvious ACL rupture without major associated injuries. A truly 'isolated' ACL rupture probably does not exist. Recent MRI studies have shown the extensive bone bruises which are present after the first injury²⁶ and which cannot be detected either clinically or arthroscopically. We have included, however, only patients with largely intact menisci and chondral surfaces since it was thought that damage to these was most likely to affect the outcome adversely.

The placement of the tunnels for ACL reconstruction is probably the single most important variable that a surgeon can control when trying to ensure a successful outcome. Jonsson and Karrholm²⁷ studied cadavers and defined the femoral ACL insertion as $27 \pm 7\%$ and the tibial position as $44 \pm 4\%$. In a further study Jonsson et al²⁴ compared the tunnel positions produced by two different surgical techniques. The first was freehand drilling of the tibial tunnel with a modified over-the-top technique (OTT) creating a trough for the femoral tunnel, and the second used an isometric drill guide system (ISO) with drilling of the femoral tunnel through the tibial tunnel. The use of the drill guide resulted in anterior graft placement at both tibial ($30 \pm 4\%$) and femoral ($34 \pm 7\%$) sites. Freehand drilling of the tibial tunnel with the OTT technique produced a more anatomical tunnel ($34 \pm 5\%$), but the femoral tunnel could not be assessed radiologically since it was a trough in the posterior femoral cortex. Their conclusion was that the OTT was superior to the ISO technique since it gave more reliable, if less anatomical, tunnel positions.

The endoscopic technique which we use allows direct visualisation of the site of the graft; by using anatomical landmarks the mean tunnel positions were closer to the anatomical sites than those produced by either of the above techniques. The femoral tunnel appears to be more critical to the outcome and should, in our opinion, be drilled independently of the tibial tunnel. We attempt to position the femoral tunnel in the posterior third of Blumensaat's line ($\leq 33\%$) and the tibial tunnel in the anterior half of the middle third of the tibial plateau (33% to 50%). By these criteria, one femoral tunnel in our series was too anterior at 40%. The fact that this graft ruptured while the patient was playing soccer 12 months after reconstruction is evidence that anterior tunnel placement, particularly in the femur, may lead to graft impingement and increase the risk of graft failure.

One of the main indications for reconstruction of the

ruptured ACL is to allow patients to return to sports, particularly those which involve side-stepping, jumping or pivoting. At the same time, ACL reconstruction should prevent the recurrent episodes of giving way that leads to meniscal damage and subsequent early joint degeneration. McDaniel and Dameron² in a study of 53 patients with a rupture of the ACL reported that 38 (72%) returned to vigorous sport without reconstruction. At a mean follow-up of ten years from injury, however, only eight knees in young patients had both menisci intact and only 13 radiographs were normal. Eight radiographs showed joint-space narrowing and three marked osteoarthritis.

Finsterbush et al²⁸ reviewed 98 patients who had had an isolated ACL rupture and found 22 cases of meniscal injury and 11 of chondral damage at a mean interval of 28 months from the time of diagnosis of the injury. Daniel and Fithian²⁵ found that the incidence of secondary meniscal surgery in ACL-deficient knees was 1.25% to 5% per year of follow-up. Although a large percentage of our patients returned to their previous level of sport no late arthroscopies were required for new meniscal tears or chondral damage during the study period. At the 24-month review, only one radiograph had deteriorated from IKDC grade A to grade B.

We evaluated the rate of return of patients to their preinjury level of activity in three different ways; the IKDC activity level, the level of competition and the estimated number of hours of participation per year. The IKDC level reflects the relative risk of damaging the ACL according to the type of sport played. Thus, level-I activities are those which involve sudden acceleration, pivoting or jumping. The ability of patients to return to level I to II activities is an indicator of a successful ACL reconstruction, and in our series 84% of patients had returned to this level at 24 months. A more critical assessment is obtained by identifying how many patients' activity levels were unchanged in any of the three categories assessed. This was 64% for males and 36% for females. No obvious factors could be identified between the two sexes to account for this difference. The demographic variables and the subjective and the objective assessments of the reconstructed knees were all comparable between men and women. Furthermore, fewer of the women who reduced their activity level said that their reconstructed knee was the principal reason for so doing. It would seem that there were other factors than those which we recorded which could account for the reduction in activity level in women.

When trying to establish the risk factors for meniscal injury and early arthritis it is important to distinguish between the effects of recurrent instability due to ACL deficiency and the deterioration of the menisci and chondral surfaces injured at the time of ACL rupture. To assess the effectiveness of ACL reconstruction at preventing instability we selected patients who did not have chondral damage at the time of reconstruction and who had largely intact menisci.

Our findings at this stage suggest that successful ACL

reconstruction performed before significant joint deterioration has occurred can preserve joint function while allowing a resumption of high-level sporting activity. Continued follow-up of this group will further define the risk of arthritis.

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