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Some clinical aspects of reconstruction for chronic anterior cruciate ligament deficiency

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A total of 250 patients was reviewed 71.8 months (range 49–105 months) after anterior cruciate ligament (ACL) reconstruction for disabling instability that had not responded to conservative treatment or correction of internal derangements. Knees that had undergone previous operation or had damage to other ligaments were excluded. Four techniques were used; MacIntosh extra-articular lateral substitution alone ($n=18$), extra-articular reconstruction plus intra-articular carbon fibre ($n=29$), extra-articular reconstruction plus a free graft from the medial third of the patellar tendon ($n=74$), or extra-articular reconstruction plus a Leeds–Keio prosthesis ($n=129$). The knees were assessed 1, 3 and 6 years after reconstruction using the Lysholm score and clinical examination for the anterior drawer, Lachman and pivot shift signs.

The mean Lysholm score after 6 years was 77.4 (range 31–100) in the extra-articular group; 74.4 (range 34–100) in the carbon fibre group; 95.4 (range 43–100) in the patellar tendon group; and 91.2 (range 45–100) in the Leeds–Keio group. The patellar tendon group had the highest scores ($P<0.003$). The pivot shift sign returned in 39% of the extra-articular group; 48% of the carbon fibre group; 1% of the patellar tendon group, and 36% of the Leeds–Keio group. The pivot shift returned least often in the patellar tendon group ($P<0.001$). There were 44% satisfactory results (pivot shift negative and Lysholm score 77 or more) in the extra-articular group; 55% in the carbon fibre group; 92% in the patellar tendon group; and 60% in the Leeds–Keio group. The patellar tendon group had the most satisfactory results ($P<0.001$).

ACL reconstruction using the medial third of the patellar tendon supplemented with a MacIntosh extra-articular reconstruction is a reliable technique for correcting chronic instability and allows most patients to return to their former level of activity, including professional sport. No support could be found for the use of prosthetic ligaments or the arthroscopic placement of ACL substitutes.

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The work described is based on more than 20 years' experience of the management of chronic ACL rupture, an interest which began while working with Dr David MacIntosh in Toronto in 1973.

The medial and lateral compartments of the knee differ anatomically. While the medial compartment has some inherent stability with a convex femoral condyle articulating with a concave tibial plateau, the lateral compartment has both a convex condyle and convex tibial plateau with no inherent mechanical stability. The only structure maintaining the lateral condyle and plateau in their correct relationship during flexion is the ACL and when this is ruptured the tibia can sublux in front of the femur under load.

The evolution of the knee offers an explanation for this instability. The earliest tetrapods had a fibulofemoral joint at the knee and this pattern persists in modern reptiles and birds *(1)*. The mammalian knee has a tibiofemoral joint only, the fibula having migrated distally to leave its former femoral articulation with the femur represented only by the lateral collateral ligament. Man is the only plantigrade mammal to walk with the knee extended and is the one most seriously affected by the mechanical inadequacy of the lateral compartment.

The subluxation and reduction of the tibiofemoral joint that follows ACL rupture was first noticed by Groves in 1920 *(2)*, but he did not relate the problem to the lateral compartment. Groves described several operations using the iliotibial tract to stabilise the knee but did not report any long-term results.

Strangely, the jerk described by Groves was disregarded by orthopaedic surgeons until rediscovered by MacIntosh in 1972 (Galway *et al. (3)*). MacIntosh's patients, many of whom were athletes, reported that when they pivoted their bones shifted. MacIntosh localised this shift to the lateral compartment and described the phenomenon as "the lateral pivot shift", a term that later became confused with the concept of rotatory instability. Like Groves, MacIntosh devised an operation to stabilise the knee using a strip of iliotibial tract. The operation was simple to perform and was successful in the short term.

A review of the results of MacIntosh extra-articular reconstruction alone *(4)* confirmed the clinical impression that the good early results were not maintained. This review coincided with Jenkins' description in 1978 *(5)* of the replacement of the ACL with filamentous carbon fibre which he believed would act as a scaffold for the regeneration of a new ligament. Carbon fibre was therefore added to the extra-articular reconstruction in an attempt to prolong the good results of isolated extra-articular reconstruction *(4)*.

Experience with carbon fibre showed this hope to be unfounded and its use was discontinued. The medial third of the patellar tendon, taken as a free graft, was used in its place, but rehabilitation was slower than with carbon fibre and problems in regaining full extension were encountered *(6)*.

At the time these difficulties were appreciated the Leeds–Keio prosthesis became available *(7)* and was used instead of the patellar tendon to replace the ACL.

The study that follows compares the outcome of these four procedures and includes a comparison of arthroscopic and open insertion of carbon fibre. All the operations were performed by one surgeon (DJD).

Patients and methods

Any patient who had undergone a previous ligament injury or sustained damage to other ligaments was excluded from the study. All patients had continuing symptoms after conservative treatment, including the correction of internal derangements by arthroscopic surgery where appropriate.

Indication for reconstruction

Recurrent subjective instability which failed to respond to physiotherapy or modification of activity was the only indication for reconstruction. This disability occurred in some patients during everyday activities and in others when they returned to a specific sport. Knee braces were used when possible but were seldom appropriate for patients with symptoms in everyday activities. Reconstruction was undertaken more readily in younger patients with athletic ambitions than in older or less active patients. All knees had a positive pivot shift sign.

Details of the patients are set out in Table I.

MacIntosh extra-articular reconstruction alone

Between 1975 and 1979, 21 patients were treated by MacIntosh lateral substitution reconstruction alone. Three (14%) were lost to follow-up, leaving 18 available for review. There were 14 men and 4 women with an average age of 24.9 years (range 17–36 years). There were 11 left and seven right knees. The mean interval between injury and operation was 34.7 months (range 6–120 months). Three knees were operated on between 6 and

Table I. Details of the patients

	Extra-articular only	*Carbon fibre*	*Patellar tendon*	*Leeds–Keio*
Men	14	25	67	101
Women	4	4	7	28
Total	18	29	74	129
Mean age (years)	24.9	25.8	27.2	29.7
(range)	(17–36)	(16–38)	(17–43)	(17–60)
Right/left	11/7	17/12	41/33	79/50
Mean interval between injury and operation (months)	34.7	33.5	32.5	48.3
(range)	(6–120)	(4–168)	(3–132)	(3–408)
Years after injury at time of reconstruction				
1	3	4	29	31
2	7	10	18	37
3	4	7	11	16
4 or more	4	8	25	45
Length of follow-up (months)	69.1	75.0	70.9	71
(range)	(49–96)	(62–91)	(60–94)	(53–105)

12 months of injury, seven between 13 and 24 months, four between 25 and 36 months and four more than 37 months after injury.

The original injury occurred in sport in 13 patients, a fall in four and a road traffic accident in one.

Operative technique

A preliminary arthroscopy was undertaken to record the presence of associated pathology and to correct internal derangements by arthroscopic surgery where appropriate. A strip of iliotibial band was raised, detached proximally, passed beneath the lateral collateral and fixed back onto the femur by stitching it to the intermuscular septum. Special care was taken to hold the strip closely against the posterior aspect of the lateral joint capsule and femoral condyle. This was the original MacIntosh repair and not the 'over-the-top' repair in which the strip is carried through the joint to replace the ligament.

MacIntosh extra-articular reconstruction plus carbon fibre

Forty patients received a MacIntosh extra-articular reconstruction combined with intra-articular carbon fibre between 1978 and 1981; 11 (27%) were lost to follow-up leaving 29 available for review *(4)*. There were 25 men and 4 women with an average age of 25.8 years (range 16–38 years). There were 17 right and 12 left knees. The mean interval between injury and operation was 33.5 months (range 4–168 months). Four knees were operated on between 4 and 12 months after injury, ten between 13 and 24 months, seven between 25 and 36 months and eight more than 37 months after injury.

The original injury occurred in sport in 25 patients, a fall in two and a road traffic accident in two.

Operative technique

In 15 knees the carbon fibre was inserted at arthrotomy. The MacIntosh extra-articular procedure was performed as described above and the incision extended medially. A tibial tunnel was made from a point 2.5 cm distal to the joint line on the medial side of the tibial tubercle to the tibial attachment of the anterior cruciate ligament. The intercondylar notch was cleared of debris and a tunnel drilled through the lateral femoral condyle passing from a point just above the femoral attachment of the lateral collateral ligament to the femoral insertion of the anterior cruciate at the back of the intercondylar notch. The carbon fibre was passed through both tunnels and the femoral end secured by a knot recessed into the femoral condyle. The prosthesis was tightened with the knee in 30° of flexion. The tibial end was then secured by a retrack tunnel passing from the distal end of the tibial tunnel beneath the tibial tubercle to the lateral aspect of the tibia. The femoral and tibial tunnels were 3.2 mm in diameter and the tibial retrack tunnel 3 mm in diameter. Passing the carbon fibre through the posterosuperior limit of the femoral attachment of the original ligament was found to give the greatest stability.

In 14 patients the carbon fibre was inserted under arthroscopic control *(8)*. The carbon fibre was passed directly across the notch; no attempt was made to cover it with synovial tissue or synovium. A tow of 40 000 strands of uncoated monofilament carbon fibre (Grafil AS, Courtaulds) was used in all knees.

MacIntosh extra-articular reconstruction plus intra-articular patellar tendon

Between February 1981 and July 1984, 103 patients received an extra-articular reconstruction combined with a free graft from the medial third of the patellar tendon; 29 (28%) were lost to follow-up leaving 74 available for review. Of the remaining 29 knees, ten were in patients resident overseas. There were 67 men and 7 women with an average age of 27.2 years (range 17–43 years). There were 41 right and 33 left knees. The mean interval between injury and operation was 32.5 months (range 3–132 months). Twenty knees were operated on between 3 and 12 months after injury, 18 between 13 and 24 months, 11 between 25 and 36 months and 25 more than 37 months after injury.

The original injury occurred in sport in 70 patients, a fall while dancing in one, a road traffic accident in two and one patient was knocked down by a pig.

Operative technique

Preliminary arthroscopy was undertaken to detect and treat any associated pathology. A lateral incision was then made from Gerdy's tubercle to a point 10 cm proximal to the lateral femoral condyle *(6)*. The skin was reflected to expose the patella and tibial tubercle. After raising the lateral collateral ligament the posterolateral corner of the knee was opened through a vertical incision long enough to admit a finger.

The medial third of the patellar tendon was identified and removed with blocks of bone from the non-articular portion of the patella proximally and the tibial tubercle distally. The patellar block included cancellous bone and was approximately 8 mm wide. The graft was kept in saline solution at room temperature until required.

The fat pad was excised, the femoral attachment of the anterior cruciate ligament identified and a recess cut at this site with a reciprocating saw. A finger in the posterolateral compartment confirmed the placement of the recess.

A tunnel was then made through the tibia to enter the joint at the anterior edge of the tibial insertion of the anterior cruciate ligament. The patellar bone block was fixed to the femur with a suture passed through two parallel drill holes. A silk suture was used in the early cases and 20-gauge wire later. The tibial bone block was then passed through the tibial tunnel and fixed with staples. The posterolateral capsulotomy was closed and a MacIntosh tenodesis performed.

MacIntosh extra-articular reconstruction combined with a Leeds–Keio prosthesis

Between November 1983 and September 1988, 160 patients received an extra-articular reconstruction combined with an intra-articular Leeds–Keio prosthesis; 31 (19%) were lost to follow-up, leaving 129 available for review. Of the remaining 31 knees, seven were in patients resident overseas. There were 101 men and 28 women, with an average age of 29.7 years (range 17–60 years); there were 79 right and 50 left knees. The mean interval between injury and operation was 48.3 months (range 3–408 months). Thirty-one knees were operated on between 3 and 12 months after injury, 37 between 13 and 24 months, 16 between 25 and 36 months and 45 more than 37 months after injury.

The original injury occurred in sport in 118 patients, a fall in six, a road traffic accident in four and one patient was injured landing a hang-glider.

Operative technique

Preliminary arthroscopy was undertaken to detect and treat associated pathology. A lateral incision was then made from a point 2 cm medial to the tibial tubercle to a point 10 cm proximal to the lateral femoral condyle *(9)*. The skin was reflected to expose the patella and tibial tubercle. After raising the lateral collateral ligament the posterolateral corner of the knee was opened through a vertical incision long enough to admit a finger, as for the patellar tendon procedure.

An incision was then made along the medial border of the patellar tendon and the fat pad retracted or excised. A tunnel was made with a bone awl from the medial edge of the patellar tendon at the upper limit of the tibial tubercle to enter the knee at the tibial insertion of the anterior cruciate ligament. A bone plug approximately 1 cm in diameter was removed from the tibia along the line of the tunnel made by the bone awl, stopping at least 8 mm short of the tibial surface. The bone plug was retained and stored in sterile saline.

The femoral attachment of the anterior cruciate ligament was then identified with a probe and a drill or hand burr passed through the tibial tunnel to enter the femur at this point. Where possible, the drill or hand burr remained within the synovial sheath of the anterior cruciate ligament. The position of the instrument was confirmed with a finger placed in the posterolateral compartment through the posterolateral capsulotomy. The instrument was then advanced to penetrate the lateral femoral cortex.

A bone plug was removed from around the path of the instrument with a gouge, stopping at least 8 mm short of the intra-articular surface of the femur. The plug was retained and stored in saline with the tibial plug.

The holes entering the joint were enlarged to 6 mm diameter and the lead string of the prosthesis passed proximally through tibia, joint cavity and femur on a malleable probe. A bone plug, with additional cancellous bone if required, was placed within the prosthesis at its femoral end and seated in the tunnel made in the femur. The bone was impacted with a punch and the prosthesis folded distally and fixed to the femur with two barbed staples. The knee was then put through a full range of movement several times while pulling firmly on the distal end of the prosthesis to hold it taut. With the prosthesis under tension, its cavity was packed with cancellous bone which was impacted with a punch. If the bone was insufficient or of poor quality, additional cancellous bone was taken from the cavity of the tibia at the distal end of the bone tunnel. Two barbed staples were then driven into the tibia over the tunnel and impacted to collapse the roof of the tibial tunnel onto the graft. The prosthesis was cut as it protruded from the bone and its end placed beneath periosteum or within the shaft of the tibia. The posterolateral capsulotomy was closed and a MacIntosh reconstruction performed.

Postoperative care

Patients treated by extra-articular reconstruction alone, those in which carbon fibre was used and the first 22 knees in the patellar tendon group were immobilised in a plaster cast at 45° of flexion and with the foot in 30° of external rotation for 6 weeks. The cast was then removed and physiotherapy begun to impove muscle strength and the range of movement. No postoperative splintage was used in the remaining patients, who were allowed active movement and weight bearing on the forefoot within the limits of discomfort.

Contact sports were prohibited until 6 months after operation, when full activity was resumed.

Assessment

Assessment was the same in all groups. The Lysholm score *(10)* was used to assess the patient's subjective evaluation of the knee. Scores below 68 were considered poor; between 68 and 76, fair; between 77 and 90, good; and above 90, excellent *(11)*.

The Lachman test *(12)*, the anterior drawer sign and the pivot shift sign were graded zero to three, with zero as normal, by subjective comparison with the opposite (normal) knee. Devices are now available for measuring anterior tibiofemoral translation but there were no reliable instruments when this study began in 1976 and grading was based on clinical examination alone. The pivot shift sign was recorded in preference to the Losee test, the Hughston jerk or the extension–rotation drawer test.

For an overall assessment of the final result, the knee was regarded as satisfactory if the Lysholm score was 77 or above and the pivot shift sign was negative, and unsatisfactory if the Lysholm score was below 77 or the pivot shift sign was positive.

Follow-up

The patients were assessed before operation and approximately 1 year, 3 years and 6 years after operation by interview or clinical examination.

Statistical analysis

Statistical comparisons within groups were made using Student's paired t test. Other comparisons were made using Student's unpaired t test and the χ^2 test.

Activity levels

No record of activity levels was available as the concept had not been proposed in 1976.

Results

Lysholm scores

The scores at 1, 3 and 6 years after operation (Table II) were significantly better than before operation in all groups (χ^2, $P<0.001$). The significance of the differences between the scores at different review periods is shown in Table III.

There was no significant difference between the scores in the extra-articular and carbon fibre groups at any stage after operation. The scores in the patellar tendon and Leeds–Keio groups were significantly better than either the extra-articular or carbon fibre groups at every stage after operation. At 1 year, the Leeds–Keio group had higher scores (χ^2, $P<0.05$) than the patellar tendon group, but the patellar tendon group had higher scores at 3 years (χ^2, $P<0.0001$) and 6 years (χ^2, $P<0.003$).

Pivot shift, anterior drawer and Lachman test

Before operation, every knee had laxity of grade 2 or 3 to all tests (Table IV). At the final review there was no difference in the incidence of the signs in the extra-articular, carbon fibre or Leeds–Keio groups, but the incidence of all three signs was less (χ^2, $P<0.001$) in the patellar tendon group than in any other.

Table II. Mean Lysholm scores before and after operation (range)

	Extra-articular only	*Carbon fibre*	*Patellar tendon*	*Leeds–Keio*
Before operation	52.7 (18–67)	49.6 (37–76)	58.3 (14–77)	57.3 (7–78)
After operation				
1 year	77.9 (61–90)	78.8 (60–95)	93.1 (59–100)	95.2 (59–100)
3 years	82.4 (36–100)	81.6 (37–100)	96.1 (50–100)	93.8 (57–100)
6 years	77.4 (32–100)	74.4 (34–100)	95.4 (43–100)	91.2 (45–100)

Table III. Significance and direction of the changes in the Lysholm scores at different review periods

	0–1 year	*1–3 years*	*3–6 years*	*1–6 years*
Extra-articular only	$+P<0.001$	NS	NS	NS
Carbon fibre	$+P<0.0001$	NS	$-P<0.03$	NS
Patellar tendon	$+P<0.0001$	$+P<0.0002$	$+P<0.03$	$-P<0.04$
Leeds–Keio	$+P<0.0001$	$-P<0.05$	$-P<0.0003$	$-P<0.0001$

Table IV. Number of patients with a positive pivot shift sign (PS), anterior drawer sign (AD) and Lachman test (L) before and after operation

	Extra-articular only			*Carbon fibre**			*Patellar tendon*			*Leeds–Keio†*		
	PS	*AD*	*L*	*PS*	*AD*	*L*	*PS*	*AD*	*L*	*PS*	*AD*	*L*
Before operation	18	18	18	29	29	29	74	74	74	129	129	129
After operation												
1 year	1	18	18	1	17	15	0	20	22	5	55	54
3 years	2	18	18	4	22	23	0	28	33	14	78	75
6 years	7	18	18	14	26	26	1	28	33	47	103	99

* In the carbon fibre group the physical signs were available in 26 patients at 6 years

† In the Leeds–Keio group the physical signs were available in 120 patients at 1 year, 104 patients at 3 years and 117 patients at 6 years

Table V. Associated pathology: the number of meniscal and articular surface lesions seen at arthroscopy before, during, and after reconstruction

	Before				*During*				*After*			
	EA	*CF*	*PT*	*L*	*EA*	*CF*	*PT*	*L*	*EA*	*CF*	*PT*	*L*
Meniscus												
Medial	2	4	14	27	4	5	16	39	4	9	2	8
Lateral	1	0	7	4	2	2	6	11	1	2	3	4
Both	0	1	3	4	0	1	3	4	1	1	2	2
*Articular cartilage**												
Medial					3	1	21	30	0	3	7	18
Lateral					2	1	16	10	1	1	6	6
Patella					1	2	7	12	2	2	7	13

* The articular cartilage changes seen at the prior arthroscopy are added to those seen at the concurrent arthroscopy

Associated pathology

The numbers of meniscal and articular cartilage lesions found at arthroscopy before, during and after reconstruction are shown in Table V. Accurate details of the articular cartilage changes at the prior arthroscopy were not always available for patients in the patellar tendon and Leeds–Keio groups because many had undergone arthroscopy elsewhere. The articular cartilage changes seen at prior and concurrent arthroscopy are aggregated in Table V to minimise error.

Overall results

The numbers of excellent, good, fair, poor and satisfactory results are shown in Table VI. The proportion of satisfactory results was greatest (χ^2, $P<0.001$) in the patellar tendon group; there was no difference between any of the other three groups. Of the patients, 44% returned to sport at their former level after MacIntosh extra-articular reconstruction alone, 34% after inserting carbon fibre, 78% with a patellar tendon graft and 66% with a Leeds–Keio prosthesis.

Complications

The incidence of complications is shown in Table VII.

Discussion

The review of MacIntosh extra-articular reconstruction alone showed the mean Lysholm score was 77 at 6 years and the pivot shift sign returned in 38% of patients. These results are inferior to some studies of reconstruction for acute injury *(13–15)*, but the patients reported here are not comparable because they had chronic anterior cruciate ligament instability and represent the failures of conservative management. The results of reconstruction for chronic instability are inferior to those of acute repair *(16)*, and the findings are similar to those *(17–19)* after extra-articular reconstruction alone for chronic instability.

Although the results of extra-articular reconstruction alone were disappointing, they could be used as a control group for the other three groups because the indications for operation and methods of assessment were identical for all four groups. This comparison showed that the addition of carbon fibre or the Leeds–Keio prosthesis to extra-articular reconstruction did not improve the results at 6 years. The Lysholm scores, the proportion of satisfactory results and the distribution of abnormal physical signs at 6 years were the same in the extra-articular, carbon fibre and Leeds–Keio groups *(4,6,9)*. The addition of carbon fibre brought an improvement in

Table VI. Lysholm score by grade* at 1, 3 and 6 years after reconstruction

	Extra-articular only			*Carbon fibre†*			*Patellar tendon*			*Leeds–Keio‡*		
	Years after operation											
	1	*3*	*6*	*1*	*3*	*6*	*1*	*3*	*6*	*1*	*3*	*6*
Excellent	4	2	2	3	8	4	4	68	65	109	101	86
Good	6	12	8	16	14	14	9	4	7	17	19	30
Fair	7	2	5	4	4	2	0	1	0	1	5	7
Poor	1	2	3	6	3	9	4	1	2	2	4	6
Satisfactory§	10	14	8	20	22	16	69	79	68	114	90	70
Percent	55	77	44	68	75	55	93	97	92	95	86	60

* Excellent >90; good 77–90; fair 68–76; poor <68 *(1)*

† In the carbon fibre group the physical signs were available in 26 patients at 6 years

‡ In the Leeds–Keio group the physical signs were available in 120 patients at 1 year, 104 patients at 3 years and 117 patients at 6 years

§ Lysholm score of 77 or more and a negative pivot shift sign

Table VII. Number and type of complication

	Extra-articular only	*Carbon fibre*	*Patellar tendon*	*Leeds–Keio*
Loss of extension	—	2 7%	17 23%	5 4%
Loss of flexion	2 11%	5 17%	12 16%	1 1%
Patellofemoral crepitus	—	—	12 16%	5 4%
Anterior knee pain	5 28%	5 17%	4 5%	0
Mechanical symptoms	—	—	6 8%	14 11%
Slight ache after use	—	—	4 5%	—
Persistent effusion	3 17%	6 21%	3 4%	1 1%
Removal of wire or silk	0	0	3 4%	0
Intra-articular adhesions	0	0	3 4%	0
Removal of staple	0	0	1 1%	2 2%
Infection (proven)	0	2 7%	1 3%	0
Infection (probable)	0	3 19%	0	0
Late infection	0	0	1 1%	0
Effusion after exercise	5 28%	8 28%	1 1%	—
Muscle hernia	1 6%	0	0	0
Tibial pain	0	7 24%	0	1 1%
Carbon fibre removed	0	8 28%	0	0
Revision reconstruction	1 6%	1 3%	0	9 7%
Deep aching	0	0	0	1 9%
Deep vein thrombosis	0	0	0	3 2%
Condylar bone cyst	0	0	0	1 1%
PVNS	0	0	0	1 1%
Total	14	48	69	54
Complications per patient	0.78	1.66	0.93	0.46

"—" indicates that the complication was not looked for

the anterior drawer and Lachman signs at 1 year, but there were more complications. The Leeds–Keio ligament was associated with fewer complications than carbon fibre or the patellar tendon graft, but the improved stability lasted for no more than 3 years.

Other authors *(8,20–24)* have shared similar disappointment with prosthetic ligaments since 1918 *(14)* and it is hard to see how the introduction of any new prosthesis can be justified until an independent follow-up study of at least 6 years has shown consistently good results.

The rôle of extra-articular reconstruction is controversial. In 1979, Butler *et al. (25)* suggested that an extra-articular reconstruction might protect an intra-articular repair from excessive loading until the new ligament had matured. This view was supported by Engebretsen *et al. (26)* who found in a cadaver study that extra-articular reconstruction reduced the load on an intra-articular graft by 43%. Noyes and Barber *(27)* later reported that allograft reconstruction combined with extra-articular reconstruction was more successful than intra-articular allograft alone, and others describe similar findings *(16,28)*.

Some authors disagree with this view and consider that extra-articular reconstruction is ineffective at best and possibly harmful. O'Brien *et al. (29,30)* found no difference between the combined procedure and intra-articular reconstruction alone after 2 years and discarded the extra-articular procedure. They also found a high morbidity attached to the extra-articular reconstruction, perhaps because the lateral staple was placed in the lateral condyle and not beneath muscle.

Although the balance of the published evidence is in favour of combining an extra-articular reconstruction with intra-articular replacement of the anterior cruciate, the procedure is not generally performed. The reasons for this are not clear, but experience with carbon fibre and the Leeds–Keio prosthesis suggests that it would be unwise to abandon extra-articular reconstruction in the absence of a proven alternative. The combination of extra-articular reconstruction with an intra-articular patellar tendon graft gave satisfactory results in 93% of knees after 6 years *(6)* regardless of the patient's age, severity of symptoms or the interval between injury and operation *(6)*. These results are superior to those of the other groups studied *(4,9)* and to other reported results *(31–33)*. The main disadvantage of the technique is difficulty in regaining full extension. Adjusting the position of the tibial tunnel, widening the intercondylar notch and aggressive physiotherapy directed to regaining full extension may all reduce the incidence of this complication.

Reconstruction using the central one-third of the patellar tendon alone is commonly performed and sometimes referred to as the 'gold standard' yet it is hard to share the widespread enthusiasm for this operation in the absence of any reports of the results after 5 or 6 years. An explanation for the popularity of this as yet unproven procedure may be that it can be performed arthroscopically.

The medial third of the patellar tendon was used in preference to the middle third and this decision avoided the problems of patellar fracture and tendon rupture *(34–*

37). It also avoided some of the problems of changes in the length of the patellar tendon reported by others *(30,38)*. Campbell *(39)* used the medial third in 1936 yet the use of the middle third, first described in 1963 by Jones *(40)*, is widespread. No argument supporting the use of the middle third of the patellar tendon in preference to the medial third could be found, except that the bone plug available from the middle third of the patella is easy to prepare for arthroscopic insertion.

Although the results of extra-articular reconstruction reinforced with the middle third of the patellar tendon are encouraging, the operation is little different from that described by Hey Groves in 1920 *(2)*. Groves used a strip of fascia in place of the patellar tendon and the extra-articular strip was passed superficial to the lateral collateral. It is disappointing to find that the energy and hard work of so many surgeons has produced such a small change in 74 years.

References

1 Dye SF. An evolutionary perspective of the knee. *J Bone Joint Surg* 1987; **69A**: 976–83.

2 Groves EWH. The crucial ligaments of the knee joint: their function, rupture and operative treatment of the same. *Br J Surg* 1920; 7: 505–15.

3 Galway RD, Beaupré A, MacIntosh DL. Pivot shift: a clinical sign of symptomatic anterior cruciate insufficiency. *J Bone Joint Surg* 1972; **54B**: 763–4.

4 Bray RC, Flanagan JP, Dandy DJ. Reconstruction for chronic anterior cruciate instability: a comparison of two methods after six years. *J Bone Joint Surg* 1988; **70B**: 100–5.

5 Jenkins DHR. The repair of cruciate ligaments with flexible carbon fibre: a longer term study of the induction of new ligaments and of the fate of the implanted carbon. *J Bone Joint Surg* 1978; **60B**: 520–2.

6 Rackemann S, Robinson A, Dandy DJ. Reconstruction of the anterior cruciate ligament with an intra-articular patellar tendon graft and extra-articular tenodesis: results after six years. *J Bone Joint Surg* 1991; **73B**: 368–73.

7 Fujikawa K, Iseki F, Tomatsu T, Takeda T, Seedhom BB. Microscopic and histological findings after reconstruction of the anterior cruciate ligament by the Leeds–Keio artificial ligament. *Knee* 1984; **10**: 35–40.

8 Dandy DJ, Flanagan JP, Steenmeyer V. Arthroscopy and the management of the ruptured anterior cruciate ligament. *Clin Orthop* 1982; **167**: 43–9.

9 Dandy DJ, Gray AJR. Anterior cruciate reconstruction with the Leeds–Keio prosthesis plus extra-articular tenodesis. *J Bone Joint Surg* 1994; **76B**: 193–7.

10 Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med* 1982; **10**: 150–4.

11 Odensten M, Lysholm J, Gillquist J. Long-term follow-up study of a distal iliotibial band transfer (DIT) for anterolateral knee instability. *Clin Orthop* 1983; **176**: 129–35.

12 Torg JS, Conrad W, Kalen V. Clinical diagnosis of anterior cruciate ligament instability in the athlete. *Am J Sports Med* 1976; **4**: 84–93.

13 Andersson C, Odensten M, Good L, Gillquist J. Surgical or non-surgical treatment of acute rupture of the anterior cruciate ligament. *J Bone Joint Surg* 1989; **71A**: 965–74.

14 Andersson C, Gillquist J. Treatment of acute isolated and combined ruptures of the anterior cruciate ligament: a long-term follow-up study. *Am J Sports Med* 1992; **20**: 7–12.

15 Cross MJ, Wootton JR, Bokor DJ, Sorrenti SJ. Acute repair of injury to the anterior cruciate ligament: a long-term follow-up. *Am J Sports Med* 1993; **21**: 128–31.

16 Simonet WT, Sim FH. Repair and reconstruction of rotatory instability of the knee. *Am J Sports Med* 1984; **12**: 89–97.

17 Dempsey S, Tregonning RJA. MacIntosh reconstruction of the anterior cruciate: comparison of lateral substitution with combined lateral substitution and intra-articular reconstruction. *J Bone Joint Surg* 1990; **72B**: 941.

18 Andrews JR, Sanders RA, Morin B. Surgical treatment of anterolateral rotatory instability: a follow-up study. *Am J Sports Med* 1985; **13**: 112–19.

19 Vail TP, Malone TR, Bassett FH. Long-term functional result in patients with anterolateral rotatory instability treated by iliotibial band transfer. *Am J Sports Med* 1992; **20**: 274–282.

20 Smith AS. The diagnosis and treatment of injuries to the crucial ligaments. *Br J Surg* 1918; **6**: 176–89.

21 Markolf KL, Pattee GA, Strum GM, Gallick GS, Herman OH, Dorey FJ. Instrumented measurements of laxity in patients who have a Gore-Tex® anterior cruciate ligament substitute. *J Bone Joint Surg* 1989; **71A**: 887–93.

22 Wilk RM, Richmond JC. Dacron ligament reconstruction for chronic anterior cruciate ligament deficiency. *Am J Sports Med* 1993; **21**: 374–80.

23 Barrett GR, Lawrence LL, Shelton WR, Manning JO, Phelps R. The Dacron ligament prosthesis in anterior cruciate ligament reconstruction. *Am J Sports Med* 1993; **21**: 367–73.

24 Lopez-Vasquez E, Juan JA, Vila E, Debon J. Reconstruction of the anterior cruciate ligament with a Dacron prosthesis. *J Bone Joint Surg* 1991; **73A**: 1294–1300.

25 Butler DL, Noyes FR, Grood ES, Miller EH, Malek M. Mechanical properties of transplants for the anterior cruciate ligament. *Trans Orthop Res Soc* 1979; **4**: 81.

26 Engebretsen L, Lew WD, Lewis JL, Hunter RE. The effect of an iliotibial tenodesis on intra-articular graft forces and knee joint motion. *Am J Sports Med* 1990; **18**: 169–76.

27 Noyes FR, Barber SD. The effect of an extra-articular procedure on allograft reconstructions for chronic ruptures of the anterior cruciate ligament. *J Bone Joint Surg* 1991; **73A**: 882–92.

28 Kornblatt I, Warren RF, Wickiewicz TL. Long-term follow-up of anterior cruciate ligament reconstruction using the quadriceps tendon substitution for chronic anterior cruciate ligament insufficiency. *Am J Sports Med* 1988; **16**: 444–8.

29 O'Brien SJ, Warren RF, Wickiewicz TL *et al.* The iliotibial sling procedure and its effect on the results of anterior cruciate ligament reconstruction. *Am J Sports Med* 1991; **19**: 21–5.

30 O'Brien SJ, Warren RF, Pavlov H, Panariello R, Wickiewicz TL. Reconstruction of the chronically insufficient anterior cruciate ligament with the central third of the patellar ligament. *J Bone Joint Surg* 1991; **73A**: 278–86.

31 Howe JG, Johnson RJ, Kaplan MJ, Fleming B, Jarvinen M. Anterior cruciate ligament reconstruction using quadriceps patellar tendon graft. *Am J Sports Med* 1991; **19**: 447–57.

32 Aglietti P, Buzzi R, D'Andria S, Zaccherotti G. Long-term study of anterior cruciate ligament reconstruction for chronic instability using the central one-third patellar tendon and a lateral extra-articular tenodesis. *Am J Sports Med* 1992; **20**: 38–45.

33 Johnson RL, Eriksson E, Haggmark T, Pope MH. Five- to ten-year follow-up evaluation after reconstruction of the anterior cruciate ligament. *Clin Orthop* 1984; **183**: 122–39.

34 McCarroll JR. Fracture of the patella during a golf swing following reconstruction of the anterior cruciate ligament: a case report. *Am J Sports Med* 1983; **11**: 26–7.

35 Lambert KL, Cunningham RR. Anatomic substitution of the ruptured ACL using a vascularised patellar tendon graft with interference fit fixation. In: Feagin JA Jr ed. *The Crucial Ligaments*. New York, etc: Churchill Livingstone, 1988: 401–8.

36 Christen B, Jakob R. Fractures associated with patellar ligament grafts in cruciate ligament surgery. *J Bone Joint Surg* 1992; **74B**: 617–19.

37 Bonamo JJ, Krinick RM, Sporn AA. Rupture of the patellar ligament after use of its central third for anterior cruciate reconstruction: a report of two cases. *J Bone Joint Surg* 1984; **66A**: 1294–7.

38 Dandy DJ, Desai SS. Patellar tendon length after anterior cruciate ligament reconstruction. *J Bone Joint Surg* 1994; **76B**: 198–9.

39 Campbell WC. Repair of the ligaments of the knee: report of a new operation for repair of the anterior crucial ligament. *Surg Gynecol Obstet* 1936; **62**: 964–8.

40 Jones KG. Reconstruction of the anterior cruciate ligament: a technique using the central one-third of the patellar ligament. *J Bone Joint Surg* 1963; **45A**: 925–32.

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