Role of abrasion of the femoral component in revision knee arthroplasty

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We carried out 60 revision procedures for failed porous coated anatomic total knee replacements in 54 patients, which were divided into two groups. The 14 knees in group I had a well-fixed femoral component at surgery which was retained, and in the 46 knees in group II both tibial and femoral components were loose and were revised using a variety of implants. Our review comprised clinical and radiological assessment.

A total of 13 knees required a second revision. Six (42%) in group I failed very early (mean 2.1 years) when compared with seven (15%) in group II (mean 6.8 years). Failure was due to wear of the polyethylene insert by the abraded, retained femoral component (crude odds ratio 4.07; 95% CI 1.07 to 15.5). We recommend a complete change of primary bearing surfaces at the time of revision of an uncemented total knee replacement in order to prevent early wear of polyethylene.

J Bone Joint Surg [Br] 2003;85-B:393-8.

Received 28 November 2001; Accepted after revision 31 October 2002

Revision for aseptic loosening in cemented arthroplasty gives satisfactory results with rates of survival which range from 30% to 83%.¹⁻⁸ The significant predictive variables for the outcome of a revision total knee replacement include local factors such as the presence of infection, a definable mechanical problem, bone loss, ligamentous integrity and systemic comorbidity.^{3,9,10} The type of prosthesis used for revision has also been shown to influence the outcome.⁶

The few studies which have been undertaken in order to assess the outcome of revision of uncemented knee replacements have only small numbers of patients. Jacobs et al³ studied a group of 28 revision knee arthroplasties. Of these, only eight were primary, uncemented porous-coated anatomic (PCA) knees. The outcome of the PCA knees was not reported separately although the group overall showed good or excellent results in 83%. This study did not assess whether revision of the femoral or tibial component alone, as compared with revision of both components, affected the outcome. Our aim therefore was to determine prospectively the 7- to 12-year results of revision surgery of the uncemented PCA knee replacement to a cemented system.

Patients and Methods

We began the study in 1989 and assessed the outcome of 66 uncemented to cemented revision total knee arthroplasties in 60 patients.

At review, four patients had died and two had been lost to follow-up. Therefore, 60 knees in 54 patients are included in this study; 32 patients had rheumatoid arthritis, 21 had generalised or post-traumatic osteoarthritis and one had juvenile chronic arthritis. There were 20 men and 34 women with a median age of the time of revision surgery of 55.7 years (22 to 84). The median body mass at the time of revision surgery was 71.1 kg (45 to 107). The median period between the primary and revision arthroplasty was 6.7 years (2 to 13). The right knee was revised in 32 knees and the left in 28. Six patients had bilateral procedures.

The indications for surgery were: suspicion of loosening in patients who had developed pain, an effusion, clinical evidence of instability, or an increasing varus or valgus deformity in a previously asymptomatic, uncemented, PCA knee arthroplasty. Weight-bearing radiographs and skyline views at 60° and 90° of flexion were compared with those

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doi:10.1302/0301-620X.85B3.13041 \$2.00

Table I. Details of the tibial inserts which were used in the 14 knees in group I

Tibial implants used at the first revision in group I	Number	Max/min thickness (mm) of polyethylene inserts			
		9/5.46	11/7.95	13/9.45	16/12.45
HDPE insert	4	3	1		
HDPE insert + tibial component	5		4	1	
HDPE + tibial component with medullary stem	5		2	2	1

Table II. Details of the implants used at the first and second revision operations for knee replacement

First revision			Second revision	
Implant	Number	Number of failures at the first revision	Implant	Number
HDPE insert	4	1	Kinemax Plus	1
HDPE insert + tibial component	5	3	Rotating hinge	2
			Superstabiliser	1
HDPE + tibial component with medullary stem	5	2	Superstabiliser	1
			Co-ordinate	1
Kinematic modular	10	2	Kinematic condylar	1
			Rotating hinge	1
Kinematic condylar	7	1	Kinemax Plus	1
Kinemax	6	1	Kinematic Condylar	1
Kinemax plus	7	0	-	-
Kinemax stabiliser	9	2	Rotating hinge	1
			Kinematic stabiliser	1
Superstabiliser	4	0	-	-
Rotating hinge	3	1	Tibial loosening-com- ponent changed	1

after the primary replacement and evidence for bone loss and/or loosening of the femoral and tibial implants was sought. The radiological indications for revision were excessive wear of high density polyethylene (HDPE), loosening, subsidence and/or fracture of the tibial base plate.

Operative technique. The senior author (IMP) performed all the operations using a medial parapatellar approach and excising the old scar. Those knees which had metallosis in association with HDPE wear had a complete, macroscopic synovectomy.

The components were exposed and their fixation assessed. When both were well fixed but with excessive wear of HDPE, only the polyethylene insert was exchanged. In those with a well-fixed femoral component, a loose tibial component and stable ligaments, the tibial component was removed, and the upper tibial surface was recut. The tibial implant was then exchanged for a cemented tibial base plate and a HDPE insert which was at least 8 mm thick. In patients with gross ligamentous instability and bone deficiency both components were replaced using a more constrained, cemented prosthesis. The metal wedges and stem size used were dictated by the amount of bone loss and the stability of the trial implant. All revision implants were cemented. Polymethylmethacrylate was used for bone defects of less than 5 mm. Four patients required the use of allograft bone. All patients received postoperative intravenous antibiotics for four days which could be changed once the synovial tissue culture and sensitivity results had been received.

Postoperatively, the patients used thromboembolic stockings for six weeks with no other form of anticoagulant prophylaxis. Weight-bearing was allowed after a postoperative radiograph was taken at 24 hours. An independent research physiotherapist scored the knees according to the Hospital for Special Surgery (HSS) Knee scoring system before operation and at three months and then yearly thereafter.¹¹

Statistical analysis. The estimated crude odds ratio was used and the 95% CI was calculated using a logarithmic transformation.¹²

Results

Details of the first revision. Of the 60 knees, four had excessive wear of polyethylene with a well-fixed femoral component and tibial base plate. In these the old polyethylene insert was exchanged for a new one with a thickness of at least 8 mm. Ten knees had a well-fixed femoral component with a loose tibial base plate which was exchanged for a cemented PCA tibial base plate. Of these, five tibial base plates required intramedullary stems for improved stability; one also required bone graft augmentation. Overall, the femoral component was retained in 14 knees. Table I shows the maximum and minimum thickness of polyethylene inserts which were used.

Patients who had complete wear of the HDPE and metallosis with loosening of both components, but with stable ligaments, received a variety of implants (Table II).

Fig. 1

Loose PCA bead found at surgery which caused third-body wear.

Fig. 2

HSS scores before and after the first revision following total knee replacement.

At surgery, we found that bone ingrowth into the femoral component corresponded to the preoperative radiological findings, while coincidental radiolucent lines around the femoral component did not imply a loose component at surgery. One patient had a fracture of the femoral component, which was not evident on the radiograph. The tibial base plate was fractured in four knees on the preoperative radiograph which matched the operative findings. Subsidence of the tibial tray and the bone loss measured before operation correlated with the amount of bone loss seen at operation.

Table III. Details of the 14 knees in group I and the 46 in group II

	Group I	Group II
Number of first revisions	14	46
Number of second revisions (%)	6 (42)	7 (15)
Mean time of second revision in years (range)	2.1 (1.8 to 2.7)	6.8 (5.5 to 7.9)
Mean weight in kg	85.5	84.6
Number of patients with rheumatoid arthritis	3	3
Number of patients with osteoarthritis	3	4
Mean age in years	54.6	55.2

Ten patients had completely worn polyethylene inserts of which four inserts had fractured. All had evidence of metal-on-metal wear and metallosis. The loose PCA beads (Fig. 1) and obvious metallosis seen at operation could not be seen from the preoperative radiographs.

Synovial culture results were positive in four knees of which three grew coagulase-negative bacteria on enriched culture medium. None had developed a clinical infection at their most recent follow-up.

The mean preoperative HSS pain score was 9.2 (0 to 50). The mean function score was 33.43 (0 to 80) and the mean total knee score was 23.7 (0 to 92). As shown in Figure 2, these scores improved to a mean postoperative pain score of 41.27 (10 to 50), a mean function score of 49.23 (20 to 95), and a mean total score of 77.27 (10 to 97) at a mean follow-up of 8.4 years (7 to 12). This represents an improvement of 53.7, 32.07 and 15.8 points in the mean total knee, pain and function scores, respectively. There were 39 excellent, 17 good and four poor results.

Details of the second revision. Of the 60 knees, 13 required a second revision. In view of this, we arbitrarily divided the 60 knees into two groups (Table III). Group I comprised the 14 knees in which only the tibial component had been changed and group II the rest (46 knees) in which both components had been revised. The variables of age, weight and type of arthritis were comparable for both groups (Table III).

Of the 14 knees in group I, six (42%) required a second revision after a mean period of 2.1 years. Of these, one had required only the insert to be changed at the first revision. The remainder required both the insert and the tibial base plate to be revised. All six knees had shown loosening of both the femoral and tibial components and macroscopic wear of the polyethylene insert. They also had gross antero-posterior instability and required revision to two superstabilisers, one rotating hinge and one co-ordinate. Two were revised to unconstrained implants.

Of the 46 knees in group II, only seven (15%) needed a second revision after a mean period of 6.8 years. The revision implants included three unconstrained prostheses, one semiconstrained prosthesis and two rotating hinges. One of the index revision rotating hinge procedures had a loose tibial component which was revised.

Fig. 3a

Fig. 3b

The abraded surface of a retrieved PCA femoral component at the second revision operation following total knee replacement.

The crude odds ratio for the two groups was 4.07 (95% CI 1.07 to 15.5). This suggested that the likelihood of a second revision was four times greater in patients in whom only the tibial component had been changed than in those in whom both components had been changed.

Discussion

The uncemented PCA knee replacement was promoted as a solution to the concerns that cemented prostheses would not withstand prolonged use in younger patients.^{13,14} It is a minimally constrained surface replacement. It was anticipated that the bone would grow into the pores and thereby confer fixation. Survivorship analysis, however, showed a disappointing rate of failure of 23% at six years.¹⁵ The main reasons for the failure were problems with the tibial component.

A polyethylene insert which was less than 8 mm thick appeared to be unable to withstand the deforming forces within the knee.¹⁶ HDPE compression moulding at high temperatures weakened the bridging fibrils between the HDPE granules and led to excessive wear.¹⁷ The tibial tray had posteriorly angulated studs, an anteriorly placed cancellous bone screw, and no central stem. The tray consistently demonstrated poor fixation with fibrous instead of bony ingrowth.¹⁸ There were only three sizes of tibial component (small, medium and large). It was impossible to achieve precise contact between the tibial tray and the cortical bone in all patients. This mismatch was another reason for failure.¹⁵

The incidence of tibial osteolysis in PCA knee replacements has been shown to be approximately 90% at a mean follow-up of seven years.¹⁹ Fixation of the tibial component without cement failed to seal the interface between the bone and the prosthesis and allowed the migration of polyethyl-

ene wear debris into the bone-implant interface, thus causing osteolysis.¹⁹

Schmalzried and Callaghan²⁰ summarised the various modes of wear in total hip and knee replacements as follows.

Mode-1 wear results from the movement which is intended to occur between two primary bearing surfaces.

Mode-2 wear refers to the wear between a primary bearing surface which moves against an unintended secondary surface. An example is the wear which occurs between the femoral component and the tibial base plate after complete wear or fracture of the polyethylene insert.

Mode-3 wear refers to the condition of the primary surfaces as they move against each other, but with the interposition of third-body particles such as cement or metal.

Mode-4 wear refers to two secondary surfaces rubbing together. Examples include movement at the stem-cement or cement-bone interface, or relative movement of a porous coating or other metal surface against bone.

In our study, six of the 14 patients (42%) in whom the femoral component was retained, required an early revision (mean 2.1 years). Only seven of 45 patients (15%) in whom both components were revised needed a second revision after a mean period of 6.8 years.

If the above concepts of models of wear are applied to our study, it is likely that the abraded retained femoral component caused excessive mode-1 wear of the HDPE insert. Experimental studies have shown that a threefold increase in the roughness of the femoral surface can cause at least a tenfold increase in the rate of polyethylene wear.^{21,22} Laboratory wear tests have shown that scratches as small as 2 µm in depth with a mean lip height of 1 µm, can increase the polyethylene wear by 30- to 70-fold depending upon the pattern of movement.²³ The number of HDPE wear parti-

cles can extend into billions for each gram of tissue.^{24,25} A foreign-body reaction occurs as the polyethylene wear particles are surrounded by multinucleated macrophages.¹⁶ These macrophage polykaryons are capable of inducing a low-grade inflammation which can result in periprosthetic bone resorption and ligamentous incompetence.^{19,26-28}

In patients with fracture of the polyethylene or complete wear, the femoral component rubs against the metal tibial base plate and may cause mode-2 wear. This may produce metal debris which acts as a third body. This debris causes mode-3 wear of the primary surfaces which further abrades both the femoral component and the polyethylene insert. The macroscopic abrasions on the surface of a femoral component which was retrieved at the second revision are shown in Figure 3.

The other source of third-body wear is the metal beads of the PCA surface. With loosening of the femoral and tibial implants, mode-4 wear occurred between the implant and bone. This resulted in the release of loose beads and further aided mode-3 wear (Fig. 1). Learmonth and Cunningham²⁹ have studied the factors which contribute to the wear of polyethylene. Third-body wear of polyethylene secondary to metal debris and loose PCA beads is well recognised.

Our results of a first revision with retention of the femoral component are disappointing when compared with those with complete change of the implants. This is mainly due to an insignificant amount of mode-1 wear in the latter group which is to be expected since the wear between the primary bearing surfaces of a new implant would be less than that between an abraded femoral component and a new polyethylene insert. Polyethylene debris may migrate into the bone-implant interface of the uncemented, retained femoral component.¹⁹ This may cause osteolysis and early failure which accords with our finding that at the second revision operation all of group I (6 knees) had loose femoral components and showed macroscopic wear of the polyethylene inserts. We emphasise that all six femoral components were well fixed at the time of the first revision.

All the revision tibial components which were used in group I were of the PCA variety and were designed to articulate with the retained femoral component. These PCA tibial components were unconstrained and not fully conforming. The bearing surfaces provided line contact, or perhaps point contact, in many circumstances. This may be a further reason why there was early failure in group I.

We recommend therefore that the femoral surface should be carefully inspected at the time of revision of PCA knee prostheses and the femoral component should be changed if there is any macroscopic evidence of abrasions. In the absence of macroscopic abrasions there may still be microscopic abrasions which can predispose to early wear of polyethylene. Furthermore, the finding of loose beads at surgery should be a definitive indication for replacing both the components since the source of the beads could be from

either of the components. Unfortunately, well-fixed femoral components may be difficult to remove, a procedure which may involve loss of bone stock. This disadvantage needs to be balanced against the replacing of an abraded femoral component thereby reducing early polyethylene wear.

Ultimately, the survival of a revision implant will depend upon an improvement in prosthetic design and a reduction in the degree of wear. There are no other comparable results in the literature for such a large series of uncemented PCA to cemented revision knee replacements. It must be remembered that our results apply only to the PCA knee replacements.

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.

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