KNEE ARTHROPLASTY USING A CEMENTLESS PCA PROSTHESIS WITH A POROUS-COATED CENTRAL TIBIAL STEM

CLINICAL AND RADIOGRAPHIC REVIEW AT FIVE YEARS

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In 44 consecutive patients, 60 porous-coated anatomic total knee (PCA) prostheses with a porous-coated central tibial stem were implanted without using cement. The clinical results and bony remodelling have been assessed after five years' follow-up.

The average Hospital for Special Surgery knee score was 33.1 before operation and 95.7 at the latest follow-up, while the average range of movement improved from 63° to 123°. No subsidence or migration of the components was seen.

A radiodense line appeared around the components at six months to one year after the operation and became more dense with time. There was no evidence of bone resorption related to stress-shielding in the tibial plateau.

An increasing incidence of loosening in cemented total knee arthroplasties has been reported (Coventry et al 1972; Bryan and Peterson 1973, 1979; Marmor 1973; Ranawat and Shine 1973; Cracchiolo et al 1979; Insall, Scott and Ranawat 1979; Borden et al 1982). Many surgeons are seeking alternative methods of implant fixation, and the use of prostheses with porous surfaces designed for biological fixation by tissue ingrowth has developed (Hungerford and Kenna 1983; Buechel and Pappas 1986; Landon, Galante and Maley 1986).

The porous-coated anatomic (PCA, Howmedica) total knee prosthesis was designed by Hungerford and his associates in 1980 (Hungerford, Kenna and Krackow 1982; Hungerford and Kenna 1983; Kenna and Hungerford 1984). It is a semi-constrained resurfacing system with porous-coating of all three components. There are two styles of tibial component: one is a resurfacing type with medial and lateral fixation pegs; the other has a central stem. The former is designed for use with or without cement; the latter is for use only with cement. The rationale for always using cement with a central stem is to avoid possible stress-shielding at the medial or

lateral tibial plateau, which could occur as a result of bone ingrowth around the stem.

Most surgeons have followed this rationale, and used the resurfacing tibial component with fixation pegs

Fig. 1

Radiograph at one year, of the left knee of a 51-year-old woman. The tibial component fixed with a screw is held up and has not settled down into a naturally stable position.

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0301-620X/90/3090 \$2.00
J Bone Joint Surg [Br] 1990; 72-B: 412-7.

for cementless replacements. However, I chose to use the tibial component with a central stem for cementless replacement. My reasons were:

- 1) Rand (personal communication 1986) reported a substantially high short-term failure rate for tibial components with medial and lateral fixation pegs;
- 2) Walker et al (1981) demonstrated in the laboratory that the least tilting occurs with a central stem on a metal tray which covers the upper tibial surface;
- 3) laterally-placed fixation pegs require undesirable destruction of cancellous bone, whereas a central stem requires removal only of the weakest part of the bone;
- 4) a tibial component with laterally-placed pegs fixed with a screw, is sometimes held up and fails to settle into a naturally stable position (Fig. 1).

This study reviews the clinical results and the bone remodelling in patients who had the cementless insertion of a PCA prosthesis with a porous-coated central tibial stem.

MATERIALS AND METHODS

At Yonsei University Medical Center, 50 consecutive patients had a primary total knee arthroplasty with cementless PCA prostheses. Six patients were lost to follow-up, so 44 have been studied. Of these, 28 had unilateral (right 13, left 15) and 16 had bilateral arthroplasties, giving a total number of 60 knees. Of the bilateral procedures, six patients had a one-stage operation, and 10 two-stages with an average interval of 14 days between the operations (range 10 days to 11 months). The mean age of the patients was 56.5 years (range 17 to 73); nine were men and 35 were women.

The underlying diagnosis was osteoarthritis in 33 knees, rheumatoid arthritis in 17, tuberculous arthritis in seven, and post-traumatic arthritis in three. No patient had had a previous operation on the involved knee. The indication for operation was serious disability of the knee because of pain and/or limited movement.

All the operations were carried out by the author and performed under general anaesthesia, using a pneumatic tourniquet. An anterior midline approach was used in 59 knees and a medial curved parapatellar incision in one with tuberculous arthritis to excise the scar of a draining sinus. Antibiotics were started during the operation and continued for two days (cephalosporin 6 g daily). Two Hemovac drains were placed in the wound, and removed at 24 hours. All patients had a postoperative dressing which included an elastic bandage over a bivalved plaster splint.

In all, 42 small, 15 medium, and three large femoral components and 34 small, 23 medium, and three large tibial components were inserted. Forty-four small and 16 medium patellar components were used. The thickness of the polyethylene of the tibial component ranged from 7 to 13 mm (average 8.2 mm).

Postoperatively, the limb was elevated and all

dressings and splints were removed at 48 hours. Static quadriceps exercises started the day after the surgery, and knee movement on the third day. Standing was allowed on the third day; walking with crutches and partial weight-bearing soon after. A pair of crutches were used for three months.

The average follow-up was 60.3 months (range 60 to 70); patients were evaluated using the Hospital for Special Surgery knee form (Insall et al 1976), a recent radiograph and scintigraphy. Function before and after the operation was analysed in terms of limp, distance walked, use of support, ability to negotiate stairs, and ability to get in and out of a chair.

The alignment and stability of the knee were assessed by clinical examination, in extension and at 30° flexion. Standing anteroposterior views and supine AP, lateral and skyline views of each knee were obtained, taking care that the central beam was directed accurately. At follow-up, fluoroscopy was used to ensure that the radiographs provided optimum visualisation of the bone-implant interfaces. Detailed analysis of the radiographs assessed alignment of the knee, and of the components, coverage of the upper tibial surface, radiodense or radiolucent lines in each of 20 zones (Kim 1988), cancellous bone densification, evidence of stress-shielding, restoration of the subchondral bone plate, and loose beads.

Scintigraphic scans were used to supplement plain radiographs, using an intravenous injection of technetium-99m phosphate and anterior, posterior and lateral views at four hours. The uptake of radionuclide was graded in each of 20 zones as: grade I, normal; grade IIa, slight increase; grade IIb, moderate increase; grade III, same level as the sacro-iliac joints; and grade IV, greater than this.

RESULTS

All patients had a significant improvement in all criteria, the average knee score of 33.1 (range 10 to 69) rising to 95.7 (range 84 to 100) at the latest follow-up. The average range of movement improved from 63° (range 20° to 95°) to 123° (range 95° to 140°). The average flexion contracture fell from 22° to 1° (maximum 10°) postoperatively.

Before operation 31 patients had a severe limp, and 13 a moderate limp; after operation, 40 had no detectable limp and four had only a slight limp. Forty of the patients could walk unlimited distances; the remaining four could walk out of doors but distances were limited by multiple joint involvement from rheumatoid arthritis.

Pre-operatively, 17 patients were unable to negotiate stairs; only two were able to ascend stairs normally, while at the latest follow-up, 22 patients could do so. All the others could ascend and descend by one step at a time, seven without using the banister and 15 using it. Before operation, 10 patients were wheelchair bound and only 10 patients did not use a walking aid. Postoperatively, 36

Fig. 2a

Fig. 2b

Postoperative radiographs of the left knee of a 56-year-old man. Figure 2a – At three months postoperatively the PCA prosthesis with a porous-coated central stem is soundly embedded. Figure 2b – At five years the prosthesis is solidly fixed and radiodense lines are visible at the interface with the tibial plateau. There is no bone resorption in the tibial plateau and he has an excellent clinical result.

Fig. 3a

Fig. 3b

Postoperative radiographs of the right knee of a 59-year-old woman. Figure 3a – At six weeks the prosthesis covers the entire upper tibial surface and the knee alignment is about 5° valgus. Figure 3b – Four years postoperatively there is a radiodense line with a radiolucent zone narrower than 1 mm at the interface of the tibial plateau. Around the central stem, there is a radiolucent line wider than 2 mm. The clinical result is excellent.

patients needed no walking aid and eight used a cane or crutch for balance.

Pre-operatively, all knees were stable, but at review two knees had some posterior instability resulting from damage to the posterior cruciate ligament during the operation. One of these patients has a catching sensation when walking downstairs, but no other pain or functional impairment. The other patient had persistent pain on

standing and required revision with a total condylar prosthesis at five years. At the revision, there was moderate posterior sagging of the tibial component with some creep deformation of the polyethylene.

The duration of operation averaged 138 minutes with an average tourniquet time of 91 minutes. Blood loss averaged 385 ml. There were no intra-operative complications or postoperative infections, though 13

knees had a haematoma which resolved with compression dressings. Hospital stay averaged 17 days (range 14 to 21) and all patients were able to walk independently with crutches at the time of leaving hospital.

The mean angles of the femoral and tibial components are given in Table I. All prostheses covered the entire upper tibial surface and no subsidence or migration was observed during follow-up. Radiodense lines appeared around the components between six months and one year after the operation and became more dense with time. A radiodense line without a radiolucent line was seen in 38.3% of the medial tibial plateaux, and 46.7% of

the lateral tibial plateaux (Fig. 2). In a higher proportion, a radiodense line with a radiolucent line less than 1 mm was seen (Fig. 3). In the bone around the central stem, 67.5% of the radiodense line was associated with a radiolucent line wider than 2 mm (Fig. 4). In the remaining 32.5%, the radiodense line was not associated with a radiolucent line or, if there was a lucent line, it was less than 2 mm wide. A subchondral bone plate in the upper tibia had reappeared in all cases after about one year (Fig. 5), and no bone resorption which could be related to stress-shielding of the tibial plateau has been seen.

Fig. 4a

Fig. 4b

Postoperative radiographs of the right knee of a 56-year-old woman. Figure 4a – Six weeks postoperatively the tibial component is seen to be fixed in slight varus with its lateral wing lifted off. Three loose beads were visible under the medial tibial plateau. Figure 4b – At five years there is restoration of the subchondral bone plate, and an organised shell of the bone is seen around the central stem.

Fig. 5

Fig. 6

Figure 5 – At one year in a 63-year-old woman, the resected subchondral bone plate in the upper tibia has been restored. Figure 6 – Scintigraphy shows normal uptake in the bone around the central stem, in the tibial plateau and in the patella.

Of the 60 implants, three showed three to 10 loose beads within three months, one involving the femur and two the tibia. Another three knees showed one to eight loose beads later, all associated with a radiolucent line wider than 2 mm and all in the patella.

Radionuclide uptake in the bone around the central stem was normal in all knees. It was abnormal in the tibial plateau of one knee, and in three patellae (Fig. 6). The abnormal uptake in the medial tibial plateau was associated with a radiodense line demarcating a radiolucent line narrower than 1 mm and no clinical symptoms (Fig. 7). However, the three cases with abnormal uptake in the patella all had suspected loosening of the patellar components with mild pain, late loose beads, and complete radiolucent lines wider than 2 mm (Fig. 8). There was a moderate increase in uptake in the distal femur in all cases, probably due to reactive changes.

The clinical results in osteoarthritis and rheumatoid arthritis were about the same, despite the difference in the quality of the bone. Two of the three loose patellar components were in osteoarthritics and one was in a rheumatoid patient.

DISCUSSION

A variety of cementless total knee prostheses are available, one of the major differences being in methods of tibial component fixation. It has been widely believed that the use of a porous-coated central stem without cement will result in stress-shielding; surface fixation with short studs or pegs has been recommended.

In my series, there has been no obvious bone resorption in the tibial plateau. There are three possible

reasons for this: 1) bone ingrowth into the central stem may have been minimal, insufficient to induce stress-shielding; 2) bone ingrowth may have been only into the soft cancellous bone around the central stem, most of the joint reaction force still acting through the tibial plateau (Bartel et al 1982; Reilly et al 1982); 3) all the tibial components covered the entire upper tibial surface, so proximal forces remained about normal (Reilly et al 1982).

The clinical significance of radiodense lines with or without radiolucent zones is uncertain. In my series, knees with a radiodense line alone at the tibial plateau all had excellent clinical results. This may indicate solid mechanical fixation. When a radiodense line was associated with a radiolucent zone narrower than 2 mm in the tibial plateau the clinical results were also excellent; this appearance probably indicates that there is a fibrous membrane between the implant and the bone. The acceptability of a thin fibrous membrane as regards long-term durability remains uncertain, but my short-term study suggests that this may be so; the membrane may function like the periodontal membrane of a tooth.

By contrast, around the central stem about two-

Table I. The mean angles (degrees) of the femoral and tibial components in 60 knees

	Anteroposterior	Lateral
Femoral component	95.5 (82 to 102)	5.7 (0 to 20)
Tibial component	87.3 (80 to 96)	88.1 (80 to 98)
Knee alignment	4.1 valgus (2.5 varus to 10 valgus)

Fig. 7a

Fig. 7b

Figure 7a - At five years, a 56-year-old woman shows solid radiographic fixation of the tibial component, with a radiolucent zone narrower than 1 mm at the tibial plateau and increased radiodensity under the medial plateau. There is an excellent clinical result. Figure 7b - A bone scan shows an increased uptake in the medial tibial plateau.

The right knee of a 56-year-old woman. Figure 8a - A lateral radiograph at four years shows loose beads and a wide radiolucent line at the bone-implant interface of the patella. She has mild knee pain. Figure 8b - A lateral bone scan shows increased uptake of radionuclide in the patella, confirming the loosening of the patellar component.

Fig. 8a

Fig. 8b

thirds of the knees showed a radiodense line with a radiolucent zone wider than 2 mm. This may be due to: 1) bone marrow tissue separating the implant from the bone at the time of introduction having later become organised; and 2) loading causing slight oscillation of the tibial component. Any oscillation should have been minimal because of the support of the tibial plateau, and should have been stabilised with time by the organised shell of bone.

Restoration of an apparent subchondral bone plate apparently resulted from joining of the cut trabeculae at the plane of bone section with bone apposition and/or ingrowth. This is an important clue that stress-shielding of the tibial plateau has not occurred.

The incidence of late loose beads (5%) was lower than in other series. This may indicate that more stable fixation was obtained by using a tibial component with a central stem. Late loosening of beads was always associated with component loosening, and should be viewed with suspicion.

The three loose patellar components showed a significantly greater uptake of radionuclide. One patient with no pain or evidence of loosening showed a moderate increase in radionuclide uptake in the medial tibial plateau; this seemed to be related to stress concentration caused by slight varus alignment of the knee. A radionuclide bone scan cannot be the sole diagnostic method in a search for prosthetic loosening or determining the significance of a radiodense line, but it seems to be a useful adjunct.

My conclusion is that cementless PCA tibial components with porous-coated central stems have shown no evidence of bone resorption due to stress-shielding after five years follow-up.

The author wishes to thank Vana E. M. Kim, EdD, for her advice and for editing the manuscript.

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

- Bartel DL, Burstein AH, Santavice EA, Insall JN. Performance of the tibial component in total knee replacement: conventional and revision designs. *J Bone Joint Surg [Am]* 1982; 64-A:1026-33.
- Borden LS, Heyne T, Belhobek G, et al. Total condylar prosthesis. *Orthop Clin North Am* 1982; 13:123-30.
- Bryan RS, Peterson LF. Polycentric total knee arthroplasty. *Orthop Clin North Am* 1973; 4:575-84.
- Bryan RS, Peterson LFA. Polycentric total knee arthroplasty: a prognostic assessment. *Clin Orthop* 1979; 145:23-8.
- Buechel FF, Pappas MJ. The New Jersey low-contact-stress knee replacement system: biomechanical rationale and review of the first 123 cemented cases. *Arch Orthop Trauma Surg* 1986; 105: 197-204.
- Coventry MB, Finerman GAM, Riley LH, Turner RH, Upshaw JE. A new geometric knee for total knee arthroplasty. *Clin Orthop* 1972; 83:157-62.
- Cracchiolo A III, Benson M, Finerman GAM, Horacek K, Amstutz HC. A prospective comparative clinical analysis of the first-generation knee replacements: polycentric vs. geometric knee arthroplasty. *Clin Orthop* 1979; 145:37-46.
- Hungerford DS, Kenna RV. Preliminary experience with a total knee prosthesis with porous coating used without cement. *Clin Orthop* 1983; 176:95-107.
- Hungerford DS, Kenna RV, Krackow KA. The porous-coated anatomic total knee. *Orthop Clin North Am* 1982; 13:103-22.
- Insall JN, Ranawat CS, Aglietti P, Shine J. A comparison of four models of total knee-replacement prostheses. *J Bone Joint Surg [Am]* 1976; 58-A:754-65.
- Insall J, Scott WN, Ranawat CS. The total condylar knee prosthesis: a report of two hundred and twenty cases. *J Bone Joint Surg [Am]* 1979; 61-A:173-80.
- Kenna RV, Hungerford DS. Design rationale for the porous coated anatomic total knee system. In: Hungerford DS, Krackow KA, Kenna RV, eds. *Total knee arthroplasty: a comprehensive approach*. Baltimore, etc: Williams and Wilkins, 1984:71-88.
- Kim Y-H. Total knee arthroplasty for tuberculous arthritis. *J Bone Joint Surg [Am]* 1988; 70-A:1322-30.
- Landon GC, Galante JO, Maley MM. Noncemented total knee arthroplasty. *Clin Orthop* 1986; 205:49-57.
- Marmor L. The modular knee. *Clin Orthop* 1973; 94:242-8.
- Ranawat CS, Shine JJ. Duo-condylar total knee arthroplasty. *Clin Orthop* 1973; 94:185-95.
- Reilly D, Walker PS, Ben-Dov M, Ewald FC. Effects of tibial components on load transfer in the upper tibia. *Clin Orthop* 1982; 165:273-82.
- Walker PS, Greene D, Reilly D, Thatcher J, Ben-Dov M, Ewald FC. Fixation of tibial components of knee prostheses. *J Bone Joint Surg [Am]* 1981; 63-A:258-67.