Original Research

Clinical Results of the Modular Porous-Coated Anatomic (PCA) Total Knee Arthroplasty With Cement: A 5-Year Prospective Study

Jonathan L. Knight, MD*
Richard D. Atwater, MD*
Louis Grothus, MS†

ABSTRACT

Our study examines the clinical, radiographic, and patient satisfaction outcome of the cemented Modular Porous-Coated Anatomic (PCA) total knee arthroplasty with a minimum 5-year follow up. All data were gathered prospectively and consecutively. Patient satisfaction was assessed with a self-administered survey. Statistical analysis examined the effect of 17 patient factors, 19 surgical factors, and postoperative continuous passive motion use on range of motion (ROM) and HSS scores at 2 years.

Seventy-eight Modular PCA arthroplasties performed by 9 orthopedic surgeons on 71 patients between January 1988 and November 1989 are reported in this study. Preoperative HSS scores averaged 51.2 and improved to an average of 89 at 1 and 2 years, and 86 at 5 years after surgery (90% good or excellent). ROM changed after surgery through improvement in preoperative knee flexion contracture, but not in increased knee flexion. One patient underwent reoperation for patellar instability, and one patient’s arthroplasty was revised at 53 months for late instability. The total reoperation rate for any reason was 7.7%. Zonal analysis for progressive radiolucency at the bone-cement interface showed increasing frequency of narrow (<1 mm) radiolucencies concentrated on the anterior and medial aspect of the tibial tray. Ninety-eight percent of patients responded to an outcome questionnaire, and 96% rated themselves improved. The Kaplan-Meier probability of an implant surviving without loosening at 5 years was 100%. The Modular PCA TKA has a low incidence of patellofemoral problems, is clinically successful, and results are stable at a minimum 5-year follow-up examination.

In 1988, the Modular Porous-Coated Anatomic (PCA) (Howmedica, Rutherford, NJ) total knee arthroplasty (TKA) was introduced to replace the Primary Porous-Coated Anatomic TKA. A femoral component of Vitalium® (Co-Cr) alloy in five sizes had design changes that included deepening and extending proximally the patellar groove, increased contact area between the patella and the femur, and enhanced radius geometry on the condyles. On the tibial side, Vitalium alloy trays in eight sizes incorporated a broad cruciate stem for better strength and resistance to rotation, a 3° posterior slope for better flexion, and a circumferential rim for improved polyethylene insert support and capture. Polyethylene insert changes included a left and right configuration with thicknesses varying from 7 mm to 19 mm, including the tibial tray. The anatomic patella's shape was modified to improve its contact with the patellar groove. These were considered evolutionary changes that would improve the fit of the implant, enhance range of motion, and minimize polyethylene wear debris generation. This article

From the *Department of Orthopedics, Group Health Cooperative of Puget Sound, Eastside Specialty Center and the †Center for Health Studies, Group Health Cooperative of Puget Sound, Redmond, Wash.

This study was supported by a grant from the Group Health Foundation. The authors thank Mr. Darin Morrow, Mr. David Einfeld, and Timothy Coglan, PA, for database maintenance and acquisition; Ms Holly Williamson for illustrations; Dr. Wallace Jones and Ms Sandra Marvinney for editorial advice; and Ms Jane Grafton for statistical programming.

Reprint requests: Jonathan L. Knight, MD, Dept of Orthopedics, Group Health Cooperative of Puget Sound, Eastside Specialty Ctr, 2700 152nd Ave NE, Redmond, WA 98052.
reports results with the Modular PCA TKA at 5 years and explores factors that contribute to better range of motion.

MATERIALS AND METHODS

Between January 1988 and November 1989, 109 consecutive primary Modular PCA TKAs were performed at Group Health Cooperative of Puget Sound’s Eastside Hospital. All information pertaining to each case was acquired prospectively. Patients who died prior to the minimum 5-year follow-up examination were excluded from the study (10 patients with 13 TKAs), as were patients who were unable to return for 5-year evaluation (16 patients with 17 TKAs). One patient with 1 TKA that was implanted without cement also was excluded. This study thus reports on 78 cemented Modular PCA TKAs in 71 patients, 7 of whom had bilateral TKA procedures.

As a hospital serving the defined population of a health maintenance organization, data on the number of patients eligible for care during the study period were available, enabling us to calculate an incidence of TKA per 100,000 patients. For those <65 years old, the incidence was 7.5/100,000, and for patients ≥65 years, the incidence was 404/100,000. For all ages combined, the incidence was 55/100,000 patients. This compares with the 1990 national figures of 15 TKAs per 100,000 in patients <65 years old and 300/100,000 in the 65 years or older population. For all ages combined, the national figures were 51.5 TKAs/100,000.

Patients were evaluated clinically using the Hospital for Special Surgery (HSS) knee rating scale. Staff in the physical therapy department performed preoperative HSS evaluations, and the operating surgeon and staff performed postoperative evaluations at 3, 6, 12, 24 months, and 5 years. Range of motion was considered poor if the arc was <90°, fair if it was between 90° and 109°, good if between 110° and 120°, and excellent if >120°. Each patient completed a patient satisfaction questionnaire at the most recent follow-up visit or by mail.

Preoperative radiographs consisted of single-leg standing anteroposterior (AP) and lateral hip/knee/ankle long cassette films, a flexed-knee lateral taken on a chest film cassette at 40 in. tube-to-film distance with a magnification marker attached to the tibial tubercle, and a 30° sunrise view of the patella. The standing films (Fig 1) were used to measure: a) the AP femoral joint to femoral shaft angle, b) the AP tibial joint to tibial shaft angle, c) AP tibiofemoral angle, d) the AP femoral shaft to mechanical axis angle, e) the lateral tibial joint to fibular shaft angle, f) the patellar height above the femur, g) the patellar height above the joint line, and h) the patella to patellar ligament ratio. The lateral flexed-knee film was used for planning tibial and femoral component sizes.

Postoperative AP and lateral films on 7 × 20-in. cassettes taken at the conclusion of surgery were used as the initial postoperative films. At 1-year postoperative follow-up examination, a set of films identical to the preoperative routine was obtained. At 2 years
and 5 years, postoperative standing 7 × 20-inch films in AP and lateral projection and a 30° patellar sunrise view were obtained.

Preoperative and postoperative films were digitized and recorded on the Orthographies Researchmetrics (Salt Lake City, Utah) computer program. All films were standardized for magnification and evaluated for angular alignment and patellar height above the femoral joint surface (Fig 1). The methods of Hungerford and Krackow were used for interface evaluation.

Statistical Analysis. Nonparametric correlations were computed and the correlations were tested to determine if they were significantly different from zero to see if there was a significant relationship between various numeric variables such as baseline age and the outcome variables such as ROM at 2 years. Analysis of variance and t-tests were used to examine the relationship between qualitative factors such as surgeon and the outcome variables of ROM and HSS at 2 years, and change in ROM and HSS from baseline to year 2. Independent variables examined included patient factors (gender, age, height, weight, preoperative diagnosis, prior surgery, knee alignment, and range of motion), operative factors (surgeon, incision, alignment of the components, use of a neutral or 2.5° varus tibial cutting block, closure of the wound in flexion or extension, surgical drain exiting medial or lateral, intraoperative knee stability), and use of postoperative in-hospital continuous passive motion (CPM).

Surgical Intervention. A team of two orthopedic surgeons and a surgical assistant performed all procedures in a standard operating room. A sandbag was placed beneath the ipsilateral hip to prevent the leg from rotating externally during surgery, and draping was done to expose the limb from iliac crest to ankle. A sterile tourniquet was applied and used within the surgical field. Preoperative antibiotics were initiated on all cases at the induction of anesthesia, and continued for 24 to 48 hours after surgery. All components were implanted with polymethylmethacrylate cement applied with a pressurizing gun after using pulsatile lavage to clean the bone surface. Thromboembolic prophylaxis was either 650 mg ASA or low-dose warfarin (Coumadin, DuPont Pharma, Wilmington, Del) began the night before surgery and continued for 6 weeks postoperatively.

Alignment devices supplied with the PCA modular TKA system were used in all cases. Femoral alignment was intramedullary and tibial alignment was extramedullary. AP tibial alignment was set from the notch between the tibial spines and extended distally to the mid-tibia just above the flare of the malleoli. The surgeon could elect a neutral or 2.5° varus tibial cut depending on the cutting jig chosen. Lateral tibial alignment was taken from the fibular head proximally to the fibular malleolus distally. Patellar resection was performed with-
TABLE 1

<table>
<thead>
<tr>
<th>Gender</th>
<th>No.</th>
<th>Age (years)</th>
<th>Height (in.)</th>
<th>Weight (lbs)</th>
<th>Diagnosis (%)</th>
<th>Charnley Rating (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>26</td>
<td>71.6 (54-86)</td>
<td>69.5 (63-78)</td>
<td>192 (114-273)</td>
<td>OA=66</td>
<td>A=21</td>
</tr>
<tr>
<td>Female</td>
<td>52</td>
<td>72 (45-90)</td>
<td>64 (59-73)</td>
<td>174 (110-249)</td>
<td>RA=9</td>
<td>B=32</td>
</tr>
</tbody>
</table>

Abbreviations: OA=osteoarthritis, RA=rheumatoid arthritis, and PTOA=post-traumatic osteoarthritis
\[n=78\]

TABLE 2

<table>
<thead>
<tr>
<th>Time</th>
<th>HSS Score</th>
<th>Extension (°)</th>
<th>Flexion (°)</th>
<th>Arc of Motion (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative (range)</td>
<td>51.2 (24-77)</td>
<td>9.7 (0-40)</td>
<td>113.6 (85-135)</td>
<td>104 (147-127)</td>
</tr>
<tr>
<td>(SD)</td>
<td>(10.9)</td>
<td>(7.8)</td>
<td>(11.8)</td>
<td></td>
</tr>
<tr>
<td>Hospital discharge (range)</td>
<td>51.5 (45-80)</td>
<td>9.2 (0-20)</td>
<td>113 (69-120)</td>
<td>84 (120-140)</td>
</tr>
<tr>
<td>3 months (range)</td>
<td>80.6 (51-98)</td>
<td>3.0 (0-18)</td>
<td>110 (70-130)</td>
<td>107 (130-160)</td>
</tr>
<tr>
<td>6 months (range)</td>
<td>86.2 (55-98)</td>
<td>2.3 (0-30)</td>
<td>114.9 (88-130)</td>
<td>113 (130-150)</td>
</tr>
<tr>
<td>12 months (range)</td>
<td>89.3 (67-99)</td>
<td>0.9 (0-10)</td>
<td>115.5 (95-135)</td>
<td>115 (135-150)</td>
</tr>
<tr>
<td>24 months (range)</td>
<td>89.7 (67-100)</td>
<td>0.8 (0-10)</td>
<td>116.7 (90-140)</td>
<td>116 (140-160)</td>
</tr>
<tr>
<td>(SD)</td>
<td>(7.8)</td>
<td>(6-9)</td>
<td>(6-10)</td>
<td></td>
</tr>
<tr>
<td>60 months (range)</td>
<td>86.3 (68-98)</td>
<td>0.9 (0-10)</td>
<td>116 (90-140)</td>
<td>115 (140-160)</td>
</tr>
</tbody>
</table>

Abbreviations: HSS=Hospital for Special Surgery and SD=standard deviation
\[n=78\]

out cutting guides, but care was taken to remove bone equal in height to the patellar implant. All patellar components were anatomic in configuration. Intraoperative ROM was recorded with a goniometer after wound closure.

RESULTS

Demographic Findings. Fifty-two arthroplasties were performed in women and 26 in men (Table 1). Of the 78 arthroplasties, 31 were performed on the left knee and 47 on the right.

Diagnosis leading to surgical intervention was osteoarthritis in 66 cases, rheumatoid arthritis in 9, and posttraumatic arthritis in 3. Eighteen cases had previous surgery: meniscectomy preceded TKA in 5, arthroscopy in 10, and high tibial osteotomy, patellectomy, or prior lateral release in 1 case each. Charnley rating of impairment found 21 cases limited only by the affected joint (Charnley A), 32 limited by the contralateral knee (Charnley B), and 25 limited by multiple joint involvement or severe medical problems (Charnley C).

Preoperative Clinical Status. The average preoperative HSS score totaled 51.2 points out of a possible 100 (Tables 2 and 3). Range of motion examination showed an average preoperative fixed flexion contracture (FFC) of 9.7°. Fourteen cases had full extension, 19 cases between 1° and 5° FFC, 17 cases between 6° and 10° FFC, and 28 cases had more than 10° FFC. The average preoperative flexion was 113.6°. Three cases had <90° of flexion, 17 had between 90° and 109°, 40 had between 110° and 120°, and 18 cases had >120° of flexion. Combining FFC and full flexion, 11 cases had 1 <90° arc of motion, 33 cases had between 90° and 109° arc, 27 between 110° and 120° arc, and 7 cases had >120° arc of motion.

Operative Data. Nine surgeons performed the 78 arthroplasties, with an average operative time of 116 minutes (SD=23; range: 75 to 194 minutes). Incision was straight anterior in 65 cases and anteromedial in 12 cases. Surgeons deflated the intraoperative tourniquet in 36 cases and did not deflate it in 42. For the tourniquet deflation group, the average estimated intraoperative blood loss was 194 mL. Femoral alignment of the cutting jig for the femoral component was 7° in 49 cases and 9° in 29 cases. Tibial alignment for the tibial cutting jig was at a right angle to the tibia in 27 cases and in 2.5° of varus in 51 cases.

Releases were performed on the lateral side in 20 instances (26%) and included 12 isolated lateral patellar retinaculum releases, 2 combined lateral retinaculum plus iliobibial band releases, and 6 combined lateral retinaculum plus iliobibial band plus lateral collateral ligament releases. No case required lateral collateral advancement. Releases on the medial side, other than the normal surgical exposure, were less frequent and included 4 isolated deep medial collateral releases and 2 isolated superficial medial collateral ligament releases.

The anterior cruciate ligament was sacrificed in all TKAs. The posterior cruciate was preserved in 77 cases and partially divided in 1. The popliteal tendon was preserved in 69 cases and divided in 9 (12%). At the completion of the surgical procedure, stability was rated as normal in 69 cases and showing mild laxity (0° to 5°) in 9 cases. Wound closure was performed in knee extension in 27 cases and knee flexion 1028
in 51 cases (65%). Surgical drains exited medially in 10 and laterally in 68 cases. Average intraoperative ROM was full extension and 125° of flexion (range: 90° to 150°). Surgeons reported no major intraoperative complications, but minor problems in 4 cases including 2 partial medial collateral ligament lacerations, 1 incorrectly cemented anatomic patella (malrotation), and 1 sewn-in drain.

Immediate Postoperative Knee Alignment. On the immediate postoperative AP and lateral films, digitizer measurements were taken to compare the pre- and postoperative alignment. Seventy-one cases (91%) were aligned in both femoral and tibial axes (Table 4). Overall tibiofemoral valgus averaged 4.4°. Tibial baseplate fit to the resected bone surface was judged excellent in 59% (no overhang, fully covered), good in 36% (>90% covered, overhang medial or lateral ≤ 5 mm), and poor in 18% (<90% covered, overhang medial or lateral > 5 mm).

Hospitalization Data. Average length of hospital stay was 8 days (SD=2, range: 4 to 20 days). CPM machines were used postoperatively on 65 cases, with the CPM started in the recovery room and used continuously until discharge from the hospital.

Medical complications were seen in 2 patients (17%): 2 urinary tract infections, 1 urethral trauma, 2 pneumonia, and 1 gouty flare; all responded to medical care during the hospitalization. One patient experienced a coagulopathy and wound bleed that was attributed to her Coumadin thromboembolic prophylaxis; the coagulopathy resolved with cessation of Coumadin treatment.

Surgical complications were encountered in 10 cases (13%). Three patients had wound hematomas that delayed wound healing, and 2 experienced delayed wound healing without hematoma. All 5 delayed wound healing cases (6%) were readmitted after discharge for further local wound care, and all healed satisfactorily. One patient had a wound cellulitis that resolved with a 10-day oral antibiotic treatment. Two cases received casts to control postoperative knee laxity; 1 had a medial collateral ligament laceration during surgery, and 1 had extensive ligament advancement as part of the correction of a valgus knee. In one case a patella subluxed with active knee extension, and the patient was entered into a rehabilitation program. One patient's postoperative drain broke during removal and the patient was returned to surgery for removal of the remaining drain tubing.

Reoperations After Hospital Discharge. One patient (1.3%) experienced patellar instability immediately after TKA. The case with patellar subluxation in extension during the initial hospitalization failed to improve with rehabilitation and underwent medial reefing with lateral release 2 months after the index procedure. Stable patellar tracking was achieved, but the patient continues to note mild pain and has had an HSS score of 77 at the 2-year and 75 at 5-year follow-up examinations.

Four additional patients (5%) had reoperation for late problems with the extensor mechanism that were not related to implant design or surgical technique. One patient fell 7 months after index TKA and ruptured the quadriceps muscle. Surgical repair was performed but the patient never recovered quadriceps strength and is unable to straighten the knee against gravity resistance. The HSS score was 76 at 2 years and 74 at 5 years after index TKA.

One patient with prior patellectomy, 28° valgus tibiofemoral deformity, and subluxed extensor mechanism underwent index TKA with proximal realignment but without patellar replacement. The extensor mechanism tracked well for 3 years, then gradually subluxed laterally again, rendering her incapable of active knee extension. At 42 months after index procedure, a proximal lateral release and distal tibial tubercle transfer were performed. At the follow-up examination, this patient had grade V quadriceps...
TABLE 4
Radiographic measurements before and immediately after surgery

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
<th>Average</th>
<th>Range</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tibiofemoral angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varus</td>
<td>N=38; 5°</td>
<td>0.3-11.3</td>
<td>2.9</td>
<td>N=7; 2.6°</td>
<td>0.5-5.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Valgus</td>
<td>N=69; 10°</td>
<td>0.2-26.5</td>
<td>7.4</td>
<td>N=71; 5.0°</td>
<td>0.3-12.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Average</td>
<td>2.7° valgus</td>
<td>4.4° valgus</td>
<td>2.5</td>
<td>98.2°</td>
<td>106.5</td>
<td>2.4</td>
</tr>
<tr>
<td>AP tibial joint to tibial shaft angle</td>
<td>98.9°</td>
<td>94-106.5</td>
<td>2.5</td>
<td>98.2°</td>
<td>106.5</td>
<td>2.4</td>
</tr>
<tr>
<td>Lateral femoral joint to femoral shaft angle</td>
<td>N=6; 65°</td>
<td>85.2°</td>
<td>77-89</td>
<td>3.0</td>
<td>75.8°</td>
<td>75-89</td>
</tr>
<tr>
<td>Patellar height above mid-femoral line</td>
<td>N=3; 93.7°</td>
<td>90-101</td>
<td>2.7</td>
<td>N=3; 91.7°</td>
<td>90-93</td>
<td>1.4</td>
</tr>
<tr>
<td>Patellar height above most distal femoral joint</td>
<td>7.1°</td>
<td>1-19</td>
<td>4.6</td>
<td>4.1°</td>
<td>3-17</td>
<td>3.3</td>
</tr>
<tr>
<td>Patella to patellar ligament ratio</td>
<td>0.6-2.0</td>
<td>0.26</td>
<td>1.02</td>
<td>0.53-1.6</td>
<td>0.27</td>
<td></td>
</tr>
</tbody>
</table>

*Abbreviations: SD=standard deviation
*n=78

strength, excellent quadriceps tracking, and a 5-year HSS score of 89.

One patient taking steroids for asthma had disruption of the patellar ligament attachment to the inferior pole of the patella at 56 months after index TKA. It took two attempts at patellar ligament reconstruction to reestablish a competent extensor mechanism. One year after the last reconstruction and 6 years after index TKA, active ROM is 110° of flexion and 5° short of full extension, and the HSS score is 82.

One patient 58 months after TKA was involved in a motor vehicle accident in which his TKA knee struck the dashboard. He experienced debonding of the all-polyethylene patellar component with shearing off of the pegs and migration of the component. Surgical revision of the patellar component was performed.

One TKA (1.3%) was revised for increasing knee instability. The index operation involved multiple ligament releases and advancement and stapling of the medial collateral ligament plus postoperative casting for valgus deformity. The patient developed progressive varus instability over time and a revision was recommended 50 months after index TKA. Revision with a total condylar 3 prosthesis (Zimmer, Warsaw, Ind) was performed elsewhere at 53 months. Surgical findings were an incompetent medial collateral ligament and posterior cruciate ligament, which allowed the tibia to sublux posteriorly and the joint to open on weight bearing, with deformation of the polyethylene insert.

No cases experienced early or late deep infection. No cases have been or are pending revision for tibial polyethylene failure. The total reoperation rate for any reason for the series is 7.7%.

2-Year Postoperative Clinical Status
The average 24-month HSS score was 89.6 points (Table 2): 62 cases (79%) had a score between 85 and 100 points (excellent), 15 cases (19%) had a score between 70 and 84 points (good), and 1 case had a score between 60 and 69 points (fair). There were no cases with a poor score (<60 points). The average improvement in HSS score was 38.4 points. Ninety-nine percent of cases had good or excellent total scores. HSS score improvement over preoperative status was significant (P<.001).

Range of motion examination showed improvement in preoperative knee FFC. The average knee extension was 1° short of full extension. At the 24-month follow-up examination, 120 cases had full extension, 13 lacked 1° to 5° of full extension, 6 lacked 6° to 10° of full extension, and no patients had a FFC >10°.

Knee flexion averaged 116.6° at 24-month evaluation, a 3° change from preoperative measurements. No cases had <90° of flexion. 16 had between 90° and 109°, 40 had between 110° and 120°, and 22 had >120° flexion. With the reduction in knee FFC, the average postoperative arc of motion improved to 116° from a preoperative measurement average of 104°. No case had an arc of motion <90°, 19 were between 90° and 109°, 38 were between 110° and 120°, and 21 had an arc of motion >120°. Improvement in the number of cases with <90° arc was highly significant, as was the improvement in average arc of motion (P<.001).

A comparison of the preoperative to the 2-year postoperative arc of motion showed that 14 cases (18%) lost motion, 5 cases had no change, 15 gained between 1° and 9°, 25 gained between 10° and 20°, and 19 cases gained more than 20° of motion. Analysis of the change in ROM between the preoperative and all postoperative examinations found that ROM improved up to 1 year after surgery, but was unchanged thereafter (Table 2). All patients with poor preoperative motion (<90° arc) improved, but patients with good or excellent preoperative motion (>110° arc) were at risk for losing motion. Forty-four percent of this group lost an average of 8° ROM arc.

Increase in ROM from preoperative to 2-year postoperative evaluation was more likely to occur in younger patients (P=.04), patients with poorer pre-
operative flexion ($P=.001$), more pre-operative FFC ($P=.001$), lower preoperative ROM ($P=.001$), and lower pre-operative HSS scores ($P=.001$). Higher patella to patellar ligament ratios postoperatively correlated with worsening ROM ($P=.001$), and lower patella to patellar ligament ratios postoperatively correlated with improvement in ROM ($P=.03$).

Analysis controlling for multiple variables (surgeon, gender, Charnley rating of impairment, diagnosis, prior surgery, intraoperative stability, closure of the wound in flexion or extension, and in-hospital CPM use) found that CPM use had a significant relationship to ROM at 2 years ($P=.01$) and to change in ROM between preoperative and 2-year postoperative ($P<.05$). Mean year 2 ROM for cases not using CPM was $107^\circ$ with a mean $-0.5^\circ$ of change, while it was $119^\circ$ with a gain of $13^\circ$ for those using CPM.

Cases that had closure of the surgical wound in flexion tended to have improved ROM over those with the wound closed in extension, but this difference was not quite statistically significant ($P=.06$). Surgical drain localization to the medial or lateral side of the suprapatellar pouch had no significant effect on ROM.

5-Year Postoperative Clinical Status.

The average 60-month HSS score was 86.4 (range: 60-98). Fifty-four cases (69%) had a score between 85 and 100 points (excellent), 16 cases had a score between 70 and 84 points (good), and 8 cases had a score between 60 and 69 points (fair). There were no cases with a score <60 points. Ninety percent of cases had a good or excellent score. The increase in patients with fair scores (60 to 69 points) between 2 and 5 years of follow up appears to be due to overall reduced level of physical activity, rather than to deterioration in objective measures of knee function. The average range of motion remained stable in terms of extension, and showed a decrease of $1^\circ$ of flexion over the values obtained at the 2-year evaluation. This change was not statistically significant.

Postoperative Interface Evaluation. Interface evaluation at 2 years and 5 years after surgery were compared with the evaluation performed on the immediate postoperative film (Fig 2). There was an increase in the number of cases with radiolucency in zones 1 and 4 of the AP tibia and in zones 1 and 3 of the lateral tibia. The lateral femoral interface zones 1 and 3 showed a smaller increase in radiolucency. Minimal changes were noted about the
patella. No circumferential radiolucency was observed on any component. Radiographs at 2 and 5 years were not fluoroscopically guided to optimize interface evaluation; so the percentage of components with a radiolucency is probably underestimated. The radiolucencies noted on the anterior and medial tibia appear to be increasing in frequency but not severity with time (none >1-mm thickness), while the femoral and patellar component show minimal change over the evaluation performed immediately after surgery.

**Outcome Survey.** Seventy-six cases responded to a questionnaire administered by mail, phone interview, or during the most recent follow-up examination. The response rate was 98%.

Forty-one percent of patients reported they never had pain in the knee, 50% reported pain occurring occasionally, 8% said it occurred with the first few steps or with all walking, and 1 patient said it occurred at all times. Evaluation of working status found 11% of patients working, 86% retired, and 3% residing in nursing homes. Level of activity was reported as sedentary by 17%, semi-sedentary (white collar job or light housekeeping) by 23%, light labor (heavy house or yard work, light sports) by 26%, moderate labor (frequent lifting of <40 lbs, moderate sports such as walking or bicycling more than 2 miles) by 32%, and heavy labor (frequent lifting of more than 40 lbs and or vigorous sports) by 1%.

Comparing function before and after surgery, 96% felt satisfied with the results of surgery, 96% reported the operation had increased their function, 96% reported decreased pain, and 95% felt the operation had decreased their need for pain medication. Of the 3 patients who were not satisfied with the TKA, I had unexplained pain and 2 had reoperations for extensor mechanism problems that were described previously.

**DISCUSSION**

The Modular PCA total knee arthroplasty evolved from the Primary PCA TKA. Results of the Primary PCA have been reported by numerous authors, but no reports have been published on the results of the Modular PCA prosthesis. The Modular PCA design sought better tracking of the patella and improved ROM and durability, while continuing to employ the Universal Knee instrumentation to guide accurate insertion of the prostheses. This prosthesis was originally available only with porous coating, but became available at less cost without porous coating toward the end of the study period. Implant costs must be considered carefully, and routinely cementing porous ingrowth designs are not recommended now that alternatives exist.

This study reports a low rate of patellofemoral problems attributable to the prosthesis (1.3%). One case experienced acute patellar tracking problems. MacCollum and Karpman reported an 11.6% incidence of patellar instability with the Primary PCA knee at a teaching hospital, attributing this high complication rate to the anatomic patellar design. Anatomic patella is not a risk factor in patellar instability, but attention to surgical technique is important in preventing this problem.

The low and unchanging incidence of patellar radiolucencies in this study suggest that cement fixation is superior to press-fit fixation of the anatomic patellar component. Only one case of patellar component loosening and revision is reported in this study, one which followed a motor vehicle accident. Kim and Oh reported a 41% failure rate with the anatomic patella unemented in a series of patients with a minimum 7-year follow up.

Range of motion following TKA is important for the functions of daily living. Kettlecamp estimated that 67° of flexion is necessary for the swing phase of gait, 83° of flexion to climb stairs, 90° to descend stairs, and 93° to rise from a medium-height chair. The reported ROM achieved by the Primary PCA has averaged 104° or less, with the singular exception of Kim's report of an average of 123° ROM in an Asian population. This study reports improved ROM for the Modular PCA to an average of 115° at 1, 2, and 5 years postoperative. We find, as Daluga et al. reported, that ROM improves up to 1 year but is stable thereafter. There is also a significant decrease in the number of cases with <90° ROM; the cases most likely to gain motion were those with poor motion preoperatively. This improvement was independent of surgeon, diagnosis, and preoperative or postoperative knee and prosthetic alignment.

ROM of the Modular PCA is favorable compared with other cruciate-sparing TKA; the Kinematic Condylar TKA has an arc of motion of 105° per Uematsu et al. The Press-Fit Condylar (PFC) TKA as reported by Tooma et al. has a ROM of 110°, with 86% of cases having better than 100° of flexion. This study finds the Modular PCA to have flexion of 115°, and 93% of patients to have >100° of flexion. The ROM of the cruciate-sacrificing Total Condylar-I is inferior, with a minimum 5-year follow-up ROM of 98°.

An uncomplicated clinical course after surgery is one of the goals of all arthroplasty surgery. The Modular PCA's cumulative reoperation rate at 5 years of 7.7% is superior to the primary PCA reoperation rate as reported by Hsu et al. of 14%, and is also superior to the calculated reoperation rate of 10% for the Total Condylar-I as reported by Insall et al.

Durability of the Modular PCA appears good at the 5-year follow up. One case has come to patellar revision after a car dashboard accident, and one case to full revision for failure of soft-tissue balancing procedures associated with the index operation. No cases have been or are pending revision for component loosening. No cases of tibial polyethylene failure have occurred to date, although this knee used the same heat-pressed polyethylene associated with a high rate of failure in the
Primary PCA knee. This case series showed a lower incidence of radiolucent lines (RLL) at longer follow up than for the radiographic review of the cemented Primary PCA knee. The distribution of radiolucent lines is the same as that reported for other designs of TKA, i.e., along the anterior and medial aspect of the tibial tray. We find the RLL to be progressive in number but not in width and believe that regular follow up is important. This may be due to more effective cement technique, or to improved design in the prosthesis.

Based on Kaplan-Meier survival analysis, with revision of any component for any reason being the endpoint, 97.5% of prostheses in this series were found to be failure-free after 5 years. With revision for loosening being the endpoint, the survival estimate shows 100% failure-free at 5 years. These results are superior to the survival of the Primary PCA knee used without cement reported after a similar period of time. These results are slightly superior but similar to the very good results (3% aseptic loosening) reported with the Total Condylar prosthesis by Insall et al at 5 to 9 years of follow up, and the Kinematic at a shorter follow-up period.

**CONCLUSION**

The clinical, radiographic, and patient satisfaction outcome of this second-generation posterior cruciate-sparing TKA demonstrate improvement over results obtained with its predecessor, the Primary PCA TKA. This report should serve as a useful baseline for longer-term analysis and underscore the importance of regular follow up for all arthroplasty patients.

**REFERENCES**


