INTRODUCTION

The patellofemoral joint continues to be the major source of problems in total knee arthroplasty (TKA). Controversy remains over the indications, or even the need for, patellar resurfacing. Randomized trials of patellar resurfacing have yielded conflicting results. To date, randomized trials of patellar resurfacing have yielded conflicting results.

The controversy over patellar resurfacing is primarily due to the numerous complications associated with this procedure, which often are difficult to treat. These complications include patellar instability, patella fracture, implant loosening, polyethylene wear, patellar tendon rupture, patellar clunk syndrome, and persistent anterior knee pain. Despite advances in implant design and surgical instrumentation, patellofemoral complications still occur in 1.5%-12% of all TKAs. These complications range from 4%-50% of all TKA revisions. To prevent or reduce these complications, research has been directed at improving the understanding of the pathomechanics of patellar resurfacing. Few studies, however, have investigated the histologic and biologic response to patellar resurfacing.

The patellar meniscus is a dense band of fibrous tissue that surrounds and sometimes covers the prosthetic patella. Cameron and Cameron noted this fibrous tissue in all 12 revision surgeries in which the patella had been resurfaced primarily. The meniscus formed within several months of the surgery and covered the patellar implant peripherally, leaving a small central facet exposed. Cameron and Cameron believed that this meniscus protected the polyethylene from abrasive wear by sharing some of the patellofemoral joint load. Matsuda et al., however, examined 2 autopsy retrieved TKAs, and found no difference in either the implant contact area or in the patellofemoral contact stress after removal of the patellar meniscus. In addition, they found no detectable contact stress in the intact patellar meniscus throughout knee range of motion. Our objective was to assess the structure and function of the patellar meniscus following successful TKA.

ABSTRACT: Twenty-four clinically successful, autopsy retrieved porous-coated anatomic total knee arthroplasty (TKA) specimens were evaluated to determine the structure and function of the patellar meniscus. Mean implant duration was 76 months (range: 11-135 months). Histological examination showed the patellar meniscus to be composed of dense fibrous tissue with scattered regions of chronic granulomatous response to polyethylene debris. Patellar wear and polyethylene exposed patellar surface area were correlated with implant duration (r=0.47, P=0.03; r=0.52, P=0.06). Postoperative patellar tilt was also associated with patellar component wear (r=0.64, P=0.03).

No other clinical measures were significantly associated with patellar wear or exposed surface area. Additional research is needed to determine what role, if any, the patellar meniscus plays in TKA outcomes.

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MATERIALS AND METHODS

Specimens were obtained at autopsy from 24 fully functional and clinically successful porous-coated, anatomic-shaped TKAs. This system included an anatomic metal-backed patellar component, which was used in every case. The polyethylene surface was dome-shaped with an extended circumferential rim to improve the polyethylene thickness along the edge of the implant. This rim was asymmetrical, extending further laterally than medially, to more closely approximate the anatomy of the normal patella. The patellar thickness was measured prior to the cuts being made. An attempt was made to restore the original thickness of the patella in every case. The cuts were then made with an oscillating saw and the patellar components were inserted without cement.

All surgeries were performed by the two senior authors (K.A.K. and D.S.H.) between 1981 and 1989. Twenty-four TKAs were performed in 19 patients (7 men [10 knees] and 12 women [14 knees]), with 5 patients (3 men and 2 women) having bilateral replacements. The right knee was replaced in 10 patients and the left knee in 14 patients. At the time of surgery, mean patient age was 67.1 years (range: 27-87 years) and mean weight was 166.4 pounds (range: 110-340 pounds). The preoperative diagnosis was osteoarthritis in 17 knees, rheumatoid arthritis in 5 knees, and osteonecrosis in 2 knees. The average time in situ for the patellar component was 75.7 months (range: 11-135 months). At the last available follow-up evaluation, mean Knee Society and Function scores were 92.2 (range: 68-100) and 77.4 (range: 20-100), respectively.

The patellar components were evaluated and the surface area of polyethylene exposed to the trochlear groove of the femoral component measured. Each patellar implant with its intact overlying meniscus was photographed, and a Research-Metrics digitizing tablet (Orthographics Inc, Salt Lake City, Utah) was used to measure the exposed surface area of the polyethylene. The meniscus was removed, and a second photograph was similarly analyzed to determine the total polyethylene surface area. The exposed surface area of polyethylene was then divided by the total surface area, and the result multiplied by 100 to obtain the percent surface area of exposed polyethylene.

The excised menisci were examined histologically by two pathologists with subspecialty training in musculoskeletal pathology. Eight samples were taken from each meniscus, fixed in formalin, embedded in paraffin, and sequentially sectioned. Each section was stained with hematoxylin-eosin, and examined under standard light and polarized light microscopy.

The patellar components were assessed for polyethylene wear using the method developed by Hood et al. All assessments were undertaken by an orthopedic surgeon, a fellow trained in joint reconstruction, and an orthopedic chief resident. Component wear was graded separately in four geometric compartments (ie, superior, inferior, medial, and lateral) of the articulating surface of the patella using low-power (10×) light microscopy. Each quadrant was evaluated for seven different modes of polyethylene wear, including delamination, pitting, abrasion, burnishing, scratching, surface deformation, and embedded polymethylmethacrylate debris. Each of these modes was graded separately for severity and for extent of wear. Severity of wear was subjectively scored as 0 (none), 1 (mild), 2 (moderate), and 3 (severe). Extent of surface wear was also subjectively scored as 0 (none), 1 (<10%), 2 (10%-50%), and 3 (>50%). To calculate a summary score, the higher the severity and extent of wear scores for each of the seven wear modes was summed in each of the four quadrants and then the quadrant scores were added together (range of possible scores: 0-84).

Anteroposterior, lateral, and skyline radiographs were available from preoperative, postoperative, and final follow-up for each knee. These radiographs were evaluated to obtain the tibiofemoral angle, mechanical axis angle, femoral joint angle, tibial joint angle, and patellar tilt. Also, the patellar component bone interface was evaluated for loosening.

Spearman rank order correlations were used to evaluate the relationship between duration of implantation, as well as various demographic, physical, and radiographic characteristics, and the two dependent variables, percent exposed surface area of polyethylene and patellar wear score. A value of $P<.05$ was considered statistically significant.

RESULTS

The total patella polyethylene surface area averaged 1043 mm², whereas the exposed area averaged 682 mm². The average percent polyethylene surface area exposed to the trochlear groove of the femoral component was 35%. Duration of implantation was correlated with the percent of exposed polyethylene surface area ($r=0.52; P=.06$), ie, as the time in situ increased, the patellar meniscus decreased in size to produce a corresponding increase in exposed polyethylene (Figure 1).

Histologic examination showed the menisci to be composed of normal synovial capsular tissue, dense fibrous connective tissue, and interspersed areas of chronic granulomatous tissue (Figure 2). These granulas contained foci of lymphocytic infiltration and clustered giant cells surrounding birefringent particles. The extracellular polyethylene debris measured 30-40 µm in size. The giant cells mainly contained ingested polyethylene particles in the 3- to 12-µm size range, although scattered intracellular particles measured up to 30-40 µm. Mononuclear
cells, probably fibrohistiocytes, contained large amounts of polyethylene debris measuring 0.5-3 µm in size.

The patellar wear scores averaged 4.3 (range: 0-16.2). Delamination followed by pitting were the two most common forms of wear observed. The regions more significantly affected by wear, in terms of both severity and percent area involved, were the medial and lateral quadrants. Over 40% of the patellar components had a score of ≥2 on at least one of the seven degradation modes examined in either the medial or lateral quadrants. Patellar component wear was correlated with the duration of implantation (r=0.47; \( P=.03 \)) (Figure 3); postoperative patellar tilt was also associated with patellar component wear (r=0.64; \( P=.03 \)). No statistically significant relationship was noted between patellar wear score and any other radiographic or demographic variable. In addition, no radiographic evidence of patellar component loosening was present in any of the specimens.

**DISCUSSION**

Patellar implant design has been technically challenging due to the biomechanical requirements of the patellofemoral joint. A minimal thickness of 10 mm is a desirable feature to help reduce wear. The thickness of the patellar component, however, is limited by several factors. First, excessive bone resection leads to an increase in patellar strain, which in turn increases the risk of patella fracture. Second, if the thickness of the implant combined with that of the remaining patella is greater than the thickness of the native patella, this leads to a decrease in motion and an increase in the patellofemoral shear forces. The overall surgical goal, therefore, is to balance the bony resection to the implant size to restore patellar thickness as closely as possible.

Component surface geometry is another aspect of implant design that has been stressed. This surface geometry varies from the low-conformity dome-shaped buttons to the intermediate-conformity bifaceted implants, and finally to the high-conformity rotating-bearing patellas. Buechel et al. mathematically analyzed the contact stresses in each of these categories of implants and found that the low-conformity and intermediate-conformity designs exceeded the yield stress of polyethylene. From these data, they predicted a high rate of polyethylene wear and early component failure. Collier et al. and Hsu and Walker confirmed these predictions in clinical specimens retrieved during component revision. The current study examined only clinically successful porous-coated anatomic TKAs, which have a low-conformity metal-backed patellar button. These implants averaged 76 months in situ and did not experience the significant wear predicted by the above studies.

The significant correlation in the study between component wear and patellar tilt suggests that surgical technique is an important contributor. Recreating the normal tracking pattern of the patella maximized the surface area for articulation with the femoral component and prevented
excessive point contact loading that would predispose to early component failure.24

The dense collagen fibers observed within the menisci in this study support a “rapid scar-type” reaction. With increasing duration of implantation, this meniscus scar regresses due to abrasive wear against the femoral component. The significant correlation between the exposed polyethylene surface area and duration of implantation observed in the present study supports this theory.

A second reason for the noted low wear scores could be the formation of the patellar meniscus itself. The initial formation of the patellar meniscus may protect the implant from excessive contact stresses. Cameron and Cameron7 have shown that the patellar meniscus is present within 2-3 months of surgery. Over time a dimensional change likely occurs in the polyethylene that increases the conformity to the femoral component. As this conformity increases, the implant is better able to distribute the contact forces over a larger surface area. This process itself increases, the implant is better able to distribute the conformity to the femoral component. As this conformity increases, the implant is better able to distribute the contact forces over a larger surface area. This process itself decreases contact stress, which in turn should minimize polyethylene wear. The meniscus becomes less necessary to determine the extent, if any, that the meniscus contributes to patellofemoral load-bearing. Laskin and Bucknell16 evaluated the patellar meniscus from five knees revised for reasons unrelated to the patella. They found a predominance of dense fibrous connective tissue with interspersed neural fibers. In our evaluation, the meniscus was composed of dense fibrous tissue and scattered areas of chronic granulomatous response to polyethylene debris. This debris may have originated from either the tibial or patellar polyethylene. The tibial polyethylene was not evaluated for wear in this investigation. It is unlikely, however, that the meniscus formed in response to the polyethylene debris, as this debris increased in quantity with implantation time while the meniscus decreased in size.

This study confirmed that the patellar meniscus is composed of dense fibrous tissue with scattered areas of chronic granulomatous response to polyethylene debris. The size of the patellar meniscus is inversely associated with duration of implantation. Wear is significantly correlated with implant duration and less than optimal surgical technique. Additional research is needed to determine what role, if any, the patellar meniscus plays in TKA success.

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REFERENCES


