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Wear of Polyethylene Against Oxidized Zirconium Femoral Components

Effect of Aggressive Kinematic Conditions and Malalignment in Total Knee Arthroplasty

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Abstract: Metallic femoral components with ceramic articulating surfaces can substantially lower polyethylene (PE) wear during walking activities under conditions of normal knee alignment. It is unknown whether these types of components can maintain low wear rates under conditions of knee malalignment and the harsher kinematics associated with younger, athletically active patients. Wear was measured in non–cross-linked, ethylene oxide–sterilized PE inserts against oxidized zirconium or cobalt-chrome femoral components in a knee wear simulator. The vertical load was modified to replicate knee varus malalignment of 3°, and the range of tibial rotation was increased to 20°. Mean gravimetric and volumetric wear rate over 5 million cycles was 55% lower in the oxidized zirconium group. An oxidized zirconium femoral component can significantly reduce PE wear under simulated conditions of athletically active patients with modestly malaligned total knee arthroplasty prostheses. **Keywords:** wear, ceramic, oxidized zirconium, total knee arthroplasty, malalignment.

Total knee arthroplasty (TKA) is a reliable surgical procedure that can alleviate pain and improve function in patients having degenerative arthritis of the knee. Numerous studies have demonstrated prosthetic survivorship of at least 90% at 10 years or more after initial surgical implantation [1-5]. Nevertheless, with increasing duration of use, prosthetic failure becomes more commonplace, with roughly 25% of all TKAs expected to fail by 20 years after surgery [4]. It is generally believed that polyethylene (PE) wear is not a major clinical concern in elderly TKA patients with optimal knee alignment [6]. Unfortunately, current data suggest that PE wear (with or without osteolysis) is a significant clinical concern in younger, athletically active patients and in patients with suboptimal component alignment [7-16]. In addition, at least 1 large study has demonstrated that although PE wear is an uncommon reason for revision in the early years after TKA, it may be the most common reason for revision when looking at all patients having revision TKA at all postoperative time points [16]. In addition, wear-related osteolysis has been reported to occur in up to 16% of well-functioning TKAs as early as 5 to 8 years postoperatively [13]. Efforts to reduce wear are warranted, particularly in younger, more active patients.

Several investigators have tried to define variables that may lead to PE wear. Malalignment is an often quoted cause of PE failure [17,18]. It has been shown that malalignment of as little as 3° can cause significant increases in contact pressures within the tibial PE insert and may be an important contributing factor leading to PE wear [18]. Studies of knee alignment after TKA have shown that deviations of 3° or more from neutral can occur in up to 72% of TKAs [19]. Younger patients, who tend to be more active than older patients, have also been found to be at significant risk for increased PE wear [17,20].

Prior studies have shown that metallic femoral components with ceramic articulating surfaces can substantially

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lower PE wear during walking activities under conditions of normal knee alignment [21]. It is unknown whether these types of components can have a positive impact on wear rates under the important conditions of modest knee malalignment and under the harsh kinematic patterns often associated with younger, athletically active patients. Our current laboratory investigation attempts to determine whether oxidized zirconium femoral components can reduce wear under conditions of malalignment and excessive tibiofemoral rotations. This is the first study we are aware of that attempts to determine whether alternative bearings can reduce wear under clinically important malaligned conditions.

Methods

Three oxidized zirconium Profix (Smith & Nephew, Memphis, Tenn) femoral components and 3 femoral components (Fig. 1) of identical geometry made of an alloy of cobalt-chrome-molybdenum (Co-Cr) were mounted in a 6-station displacement-controlled knee wear simulator (AMTI, Watertown, Mass). The femoral components were articulated against 6 tibial PE inserts (non–cross-linked, sterilized by ethylene oxide) in modular tibial base plates. The lubricant used was 90% bovine serum supplemented with EDTA and sodium azide. The fluid was changed after every 500 000 cycles. The knee components were subjected to 5 million gait cycles based on the International Organization for Standardization (ISO) recommendations [21] with the following modifications. The mediolateral distribution of the vertical tibial load was increased to 75:25 (from the ISO-recommended 60:40 distribution) to represent the distribution of load because of the mechanical axis of the knee passing more medially through the joint line. This approximates 3° of varus malalignment [22-24]. Furthermore, the magnitude of tibial axial rotation was increased to 20° to simulate the high rotational tibiofemoral movements that occur with pivoting and twisting. These conditions were chosen to simulate an athletically active patient with less than optimal knee alignment.

Fig. 1. Photograph of oxidized zirconium (left) and cobalt-chrome femoral component (right).

Wear was measured using a surface mapping technique (Fig. 2) as well as using gravimetric (weight loss) analysis. The articular surface of each PE insert was mapped by using a motorized XY stage (SG20-85; Sigma Koki, Tokyo, Japan) and a laser displacement sensor with a resolution of 3 μm (LK-081/086; Keyence Corp, Los Angeles, Calif). The inserts were mounted on the XY stage, and the 3-dimensional points on the surface were digitized at 250-μm intervals along the x- (mediolateral) and y- (anteroposterior) axes. These points were connected to generate a surface map of the articular surface. Surface maps were constructed from measurements made before wear testing, at approximately 2.5 million and 5 million cycles of testing. Volumetric wear was computed by comparing surface maps of inserts at the completion of 2.5 million and 5 million cycles. It was assumed that creep was negligible after 2.5 million cycles and that the subsequent volumetric measurements reflected true wear rates of the articular surface [25]. Volumetric wear was converted to weight loss by multiplying volumetric wear by the nominal density of PE (0.93 mg/mm^3). Gravimetric wear was measured by weighing the PE inserts at approximately 500 000 cycle intervals. Soaked controls were used to correct for weight gain due to fluid absorption.

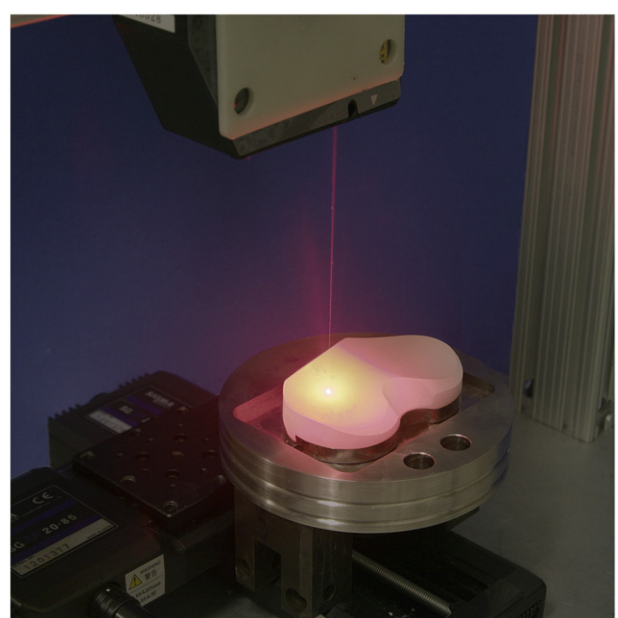

Fig. 2. Photograph of laser surface mapping system. Surfaces of the tibial PE inserts were mapped before testing and after 2.5 million and 5 million cycles of wear testing to compute volumetric wear rates.