

Comparing Polyethylene Wear Debris from CoCr and TiN-Coated Femoral Components

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Introduction

It is well known that the size and volume of polyethylene wear particles have one of the greatest effects on bioreactivity and osteolysis. Polyethylene particles in the 0.1-to-10-micron range have been shown to be the most bio reactive historically (1). Also, surface roughness of femoral components can influence polyethylene wear rate in total knee replacements. Cobalt chromium (CoCr) femoral components, which have demonstrated strong survivorship and patient satisfaction, have been compared to alternative materials (i.e., oxidized zirconium) that have demonstrated less surface roughness via surface profilometry and therefore less wear debris (2; 3; 4). Alternative coating on bearing surfaces, such as titanium nitride (TiN), has been introduced to reduce exposure to common metal sensitizers (5). As such, in this knee simulator study, we sought to evaluate polyethylene wear particle size and morphology generated with a TiN-coated femoral component compared to a CoCr femoral component.

Methods

Three Titanium Nitride (TiN) coated Ti-6Al-4V substrate femoral components and three CoCr femoral components of equivalent surface geometry were utilized for this study. All femoral components were size 1 and articulated on a corresponding size 1, 9mm thick highly crosslinked UHMWPE tibial insert seated in a size 1 titanium baseplate. All components were cleaned and weighed prior to test setup. In addition, White Light Interferometry (WLI) was obtained on all femoral components to obtain the surface roughness prior to testing.

A six-station knee joint simulator was utilized and all components tested in accordance with ISO 14243-3 (6). The femur was cemented with bone cement to the flexion arm fixture which provided flexion as well as anterior-posterior (AP) translation of the femur with respect to the tibia. The tibial insert was placed in the tibial baseplate which was cemented into the tibial specimen chamber and centered under the femoral component. The axial load and internal-external (IE) rotation were provided through the tibial specimen chamber via an axial/torsional actuator. The tibial specimen chambers were filled with Alpha Calf Fraction serum (Hyclone Labs, Logan, UT) to ensure the specimens were fully submerged and lubricated during testing. The Alpha Calf Fraction serum was diluted to 50% using DI water to obtain a physiologically relevant protein level (20 g/L) and combined with Gentamicin (5mL/L) and Amphotericin (10 mL/L) to retard serum decomposition (7). Testing was conducted for 5.0 million cycles (mc) with the test stopping every 0.5 mc to clean the tibial inserts and change the serum.

At the completion of testing, serum from the final interval (4.5-5.0 mc) was sent to an outside vendor (Lucideon M+P, Greenville, SC) for testing to characterize the polyethylene particles. Serum from each simulator station was stirred, poured into a sterile container, refrigerated, and shipped overnight. The serum was digested, and the particles were isolated and characterized in accordance with ISO 17853: 2011 and ASTM F1877-16 (8; 9). Measurements were provided for the following parameters in accordance with ASTM F1877-16: aspect ratio, perimeter, form factor, roundness, equivalent circle diameter (ECD), and feret diameter (or length; representative of the particle size). A two-sample Mann-Whitney U test was conducted at a 95% confidence level ($\alpha = 0.05$) to determine whether the median feret diameters of the two populations were significantly different.

Results

Figure 1 shows the mean particle morphology and size parameters for the CoCr and TiN-coated populations. All particles fell in similar size ranges for each parameter studied. The feret diameter (or length; representative of the particle size) is within the range of 0.1 to 10 μ m typically reported in literature for polyethylene debris from total joint replacement (10; 1). Furthermore, the feret diameter for the TiN-coated group was found to not be significantly different ($p = 0.114$) than the CoCr group, suggesting that the osteolytic response for both groups will be similar.

Discussion

In evaluating the size and morphology of the polyethylene particles in this knee simulator study, no significant differences in particle generation between the TiN-coated and CoCr femoral components were observed. Overall, the particles that were generated were between 0.1 to 10 μ m which is typical of wear particles from total joint replacement bearings (10; 1).

Significance

The polyethylene particles generated with a TiN-coated femoral component are similar in size and morphology to the particles generated from a CoCr femoral component. Implants with TiN coating may offer surgeons an alternative option for patients with common metal sensitivity concerns (5), without increasing the potential for polyethylene wear.

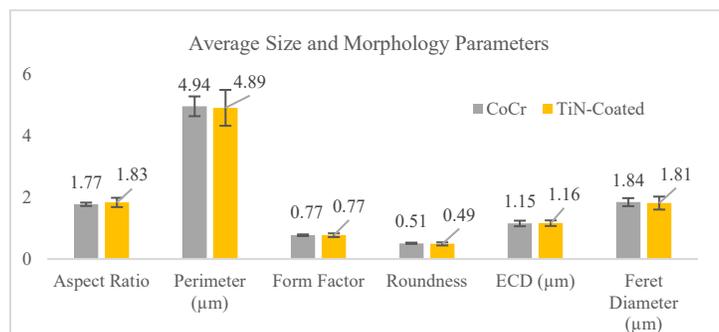


Figure 1: Mean particle morphology and size measurements per population group

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