Wear Comparison of CoCr Femurs to TiN-Coated Femurs

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Introduction

Surface roughness of femoral components can influence polyethylene wear rate in total knee replacements (1). Traditional cobalt chromium (CoCr) femoral components, which have shown strong clinical 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 compare TiN and CoCr femoral components and evaluate the differences in polyethylene wear.

Methods

Three Titanium Nitride (TiN) coated Ti-6Al-4V substrate femoral components and three CoCr femoral components, all 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 and weigh the tibial inserts, as well as obtain WLI data on the femoral components.

At the completion of testing, all components were visually inspected for signs of wear. In addition, the average and standard deviation for the WLI data of each group was determined. Lastly, the mass data from the tibial inserts was utilized to determine the gravimetric weight loss and to convert the gravimetric weight loss to volume loss and volumetric wear rate in accordance with ISO 14243-2 (8) and ASTM F2025 (9). A two-sample equivalence test, with a confidence level of 95% and equivalence margin of 2.00 mm^3/mc, was performed to determine if the average volumetric wear rate was equivalent between groups.

Results

The worn tibial inserts for the two groups showed typical wear polishing or burnishing, deformation, striations, and scratches with no visual differences between groups. Light surface scratches were observed for all femoral components. As seen in Figure 1, the surface roughness of the TiN-coated Ti-6Al-4V femoral components remained unchanged throughout the course of testing. Looking at the corresponding wear rate of the tibial inserts (Figure 2), they were found to be equivalent with a p-value of 0.010.

Discussion

The results of this knee simulator study demonstrated only mild wear of the polyethylene inserts in both the TiN and CoCr femoral component groups. In addition, it was noted that the TiN-coated femoral components had no change in surface roughness throughout the experiment despite light surface scratching. This contrasted with the CoCr femoral components that had a slight increase in surface roughness over time.

Significance

The polyethylene volumetric wear rate with a TiN-coated femoral component was similar to the wear rate generated from a traditional 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.

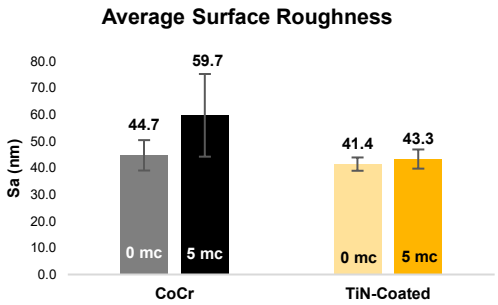

Figure 1: Average surface roughness (Sa) for each study group before and after 5.0 mc of testing

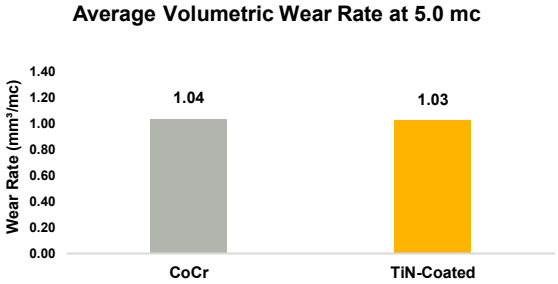

Figure 2: Average volumetric wear rate throughout 5.0 million cycles (mc) of testing

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