Wear of Pyrocarbon and Metal Against Cortical Bone in a Joint Simulator

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Statement of Purpose: A new modular radial head design prepared from pyrolytic carbon (PyC) was tested to characterize wear against cortical bone for hemiarthroplasty applications. A cobalt chromium (CoCr) alloy modular radial head version of the design was tested for comparison.

Methods: Modular radial heads were prepared from unalloyed fluidized bed pyrolytic carbon (Medical Carbon Research Institute) and from ASTM F1537 CoCr alloy. The heads were loaded with 40 lb axial load and articulated through a 47° angle in a joint simulator. Dilute calf bovine serum (MP Biomedicals, Inc. Aurora, OH), 1:1 in DI water was used as the lubricant. Cortical bone counter-faces were prepared from plugs sampled from a single bovine femur. A spherical radius of approximately 1 inch was machined on the bone plug surface. The test was run to 5 million cycles at 4 Hz with sampling at 0.5, 1, 2.5 and 5 million cycles. At each sampling interval, specimens were visually examined using a stereo-microscope, photographed, bone plug height measured, radial head surfaces characterized by optical profilometry and the lubricant sampled. Optical profilometry was performed using a Wyco 500 system (Veeco, Tucson, AZ). After digestion of all bone debris and salts in the lubricant, particle counts were performed on the final pellet and first supernatant solutions using the Spectrex PC-2000 Laser Particle Counter (Spectrex Corp., Redwood City, CA). Bone plug heights were measured using a profile projector.

Results/Discussion: It was necessary to remove the CoCr control from the test at 5×10^5 cycles because the available bone on the counter-face had been consumed. All of the PyC specimens and bone counter-faces survived the 5×10^6 cycle run-out. Bone heights as a function of cycles are shown below in figure 1.

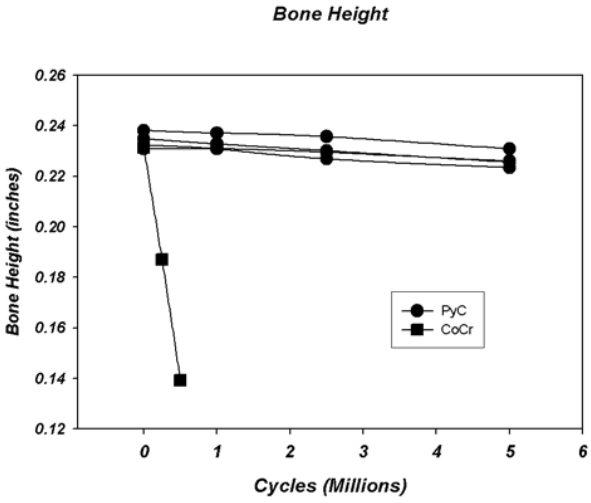

Figure 1. Bone height as a function of cycle number.

Surface quality of PyC at 5 million cycles and CoCr at 5×10^5 cycles is illustrated in figure 2. Surface finish for the CoCr specimen increased from a pretest Rq value of 0.033 to 2.55 micrometer post test. Post test scratches in CoCr were on the order of 10 micrometer depth. PyC head Rq surface finish increased only slightly from 0.039 pretest to 0.049 micrometer post test and exhibited only minor surface scratches of 0.86 micrometer maximum depth. A summary of surface finish observations is given below in Table 1.

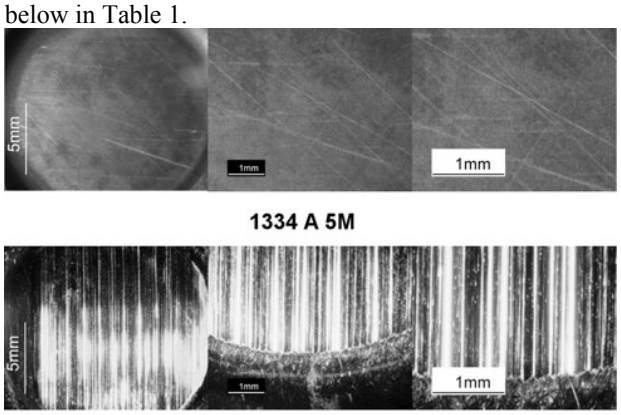

Figure 2. Surface quality of PyC at 5 million cycles (top) and CoCr at 5×10^5 cycles (bottom).

Table 1. Radial Head Surface Finish (μm)

Roughness Quantity	PyC	CoCr
Pre Test Rq	0.039 ± 0.007	0.033 ± 0.006
Post Test Rq	0.049 ± 0.009	2.55
Max scratch depth	0.86 μm	10.0 μm

Particle counting did not detect a measurable increase in PyC particles throughout the test. Particles for the CoCr increased approximately 8700 percent over 5×10^5 cycles relative to the pre-test count.

Conclusions: Minor wear damage occurred to the PyC and bone counter-faces over 5×10^6 cycles. No detectable amounts of PyC wear debris were generated. The CoCr and bone counter-faces developed profound wear damage after only 5×10^5 cycles. A remarkable amount of CoCr wear debris was generated. It is concluded that articulating PyC against bone results in much less damage to bone tissue than does the Co-Cr alloy. Therefore, it is reasonable to expect that PyC can potentially extend the useful life of implants in hemiarthroplasty applications relative to CoCr.