Wear Rate Comparison between Polycrystalline Diamond, CoCr, and UHMWPE in High Wear Environments

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Purpose: Total disc replacement (TDR) devices have been restricted to designs with large, congruent articulations due to the limited wear properties of available orthopedic materials. TDRs that facilitate more natural motion could be designed if there were materials available which could resist the higher wear conditions. For example, Dimicron’s aggressive TriLobe design is self-centering and energetically stable, and it emulates the natural motion of an intact intervertebral disc, but is not feasible using traditional materials due to its small, incongruent articulating surfaces. The objective of this study was to compare the wear properties of Dimicron’s medical grade polycrystalline diamond with wear properties of cobalt chrome (CoCr) and ultrahigh molecular weight polyethylene (UHMWPE) in aggressive high wear conditions.

Methods: A modified pin-on-disc, crossing-path wear test was used to measure the wear rates of PCD-on-PCD, CoCr-on-CoCr, and CoCr-on-UHMWPE. The discs were placed in the inferior position on an oscillating plate, moving in a figure-eight pattern. The figure-eight motion was 10mm long by 5mm wide. The pins had an initial 11.5mm radius and were loaded at 133N normal to the disc. In a typical pin-on-disc test, a wear flat develops on the pin and the wear rate is reduced as the contact area increases. The TriLobe design uses three lobes sliding in three non-conforming lenses which prevents wear flats from developing. To better approximate this condition, the fixture holding the disc was placed on an air bearing and was allowed to rock in response to the movement of the load. The test took place in 25% bovine serum, and at a speed of less than two Hertz. Two sets of each material were tested, one set to 2.0 million cycles and the other set to 14.0 million cycles. Wear rates on the rocking-discs were measured using a high resolution coordinate measuring machine because the wear in the PCD specimens was not detectable gravimetrically.

Results: The diamond specimen averaged 0.0036mm³/MC of wear over the first 2 million cycles. The CoCr-on-CoCr specimen averaged 1.4mm³/MC and the CoCr-on-UHMWPE averaged 4.7mm³/MC over 2 million cycles. The PCD specimen taken to 14 million cycles had an average wear of 0.0022mm³/MC compared to 2.4mm³/MC and 9.5mm³/MC for CoCr-on-CoCr and CoCr-on-UHMWPE respectively.

Conclusions: Using the pin-on-rocking-disc test to approximate small, non-congruent articulating surface wear, both CoCr-on-CoCr and CoCr-on-UHMWPE wore at rates that were orders of magnitude greater than medical grade PCD. At two million cycles, CoCr-on-CoCr had worn nearly 400 times more than PCD and CoCr-on-UHMWPE wore more than 1300 times greater. During the last 12 million cycles the wear in non-diamond specimen accelerated, while the diamond wear rate decreased. At the end of 14 million cycles CoCr on itself and on UHMWPE specimens had worn at more than 1100 times and nearly 4300 times greater than PCD, respectively. Coupled with the inherent biocompatibility, high strength and toughness, and ultra low friction of diamond, the wear performance of PCD makes it an attractive material for TDR applications. PCD could be used in current designs to alleviate concern over wear debris and ion release, or it be used to open up the design space for the next generation of TDR devices.

[Fig.1 Pin-on-Rocking-Disc Set-up]