LUBRICATION AND WEAR OF ZIRCONIA-ON-METAL TOTAL HIP REPLACEMENTS

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ABSTRACT

Hard-on-hard total hip replacements such as metal-on-metal and ceramic-on-ceramic couplings are currently being investigated as alternatives to the conventional metal or ceramic-on-polyethylene configurations. Alumina-on-metal configurations have recently been shown to exhibit exceptionally low wear rates [1, 2]. In this study the alternative coupling of zirconia-on-metal has been explored. Zirconia-on-metal joints were tested in 25 % bovine serum using a hip simulator. The joints were subjected to simulated dynamic motion and loading walking cycles and wear was measured gravimetrically. To investigate the effect of diameter, 22.225 mm and 28 mm diameter joints with mean diametral clearances of approximately 90 µm were tested. The effect of diametral clearance was investigated in further tests on joints of 22.225 mm diameter, but with a mean diametral clearance of 54 µm.

The wear of four 22.225 mm diameter zirconia-on-metal joints with diametral clearances of approximately 90 µm was found to be linear over a wear test extending to 1.2 million cycles. The mean volumetric wear rate and standard deviation for the 22.225 mm joints were 6.92 ± 2.01 mm³/10⁶ cycles over the full duration of testing. Three further 22.225 mm joints with a mean diametral clearance of 54 µm showed two distinctive periods of wear over 2 million cycles of testing. An initial high wear period was observed up to 350,000 cycles as the joints bedded-in. This was followed by a lower wear rate thereafter. The mean long-term steady-state wear rate from 350,000 to 2 million cycles was 1.62 ± 0.88 mm³/10⁶ cycles. This wear rate is less than a quarter of that for joints with the same diameter but larger diametral clearances.

Three 28mm diameter zirconia-on-metal joints with approximately 90µm diametral clearances produced varied wear curves over 5 million cycles of testing. The mean steady-state, long-term wear rate for these joints was 0.68 ± 0.87 mm³/10⁶ cycles, slightly over an order of magnitude lower than the wear rate of the smaller 22.225 mm joints with similar diametral clearances.

For all of the joints tested, wear damage was restricted almost entirely to the metal acetabular cup insert. This allowed the 28 mm diameter zirconia-on-metal joints to bed-in quicker than the 28 mm metal-on-metal joints, previously tested [3]. Zirconia-on-metal joints may thus provide a suitable low-wearing alternative to other hard-on-hard total hip replacements. Wear rates were significantly lower than metal-on-metal joints of similar geometry. Furthermore, the time required for the 28 mm diameter zirconia-on-metal joints to bed-in was less than that of the 28 mm metal-on-metal joints, thus reducing the amount of wear debris produced.

Maintaining diametral clearance but increasing femoral head diameter of the zirconia-on-metal joints, from only 22.225 mm to 28 mm, reduced the mean wear rate by over an order of magnitude. Similarly, reducing diametral clearance for a fixed femoral head diameter resulted in a four-fold reduction in the mean wear rate. Both these findings are consistent with operation in the mixed lubrication regime and the form of the Stribeck curve. The increasing contribution of effective lubrication to the reduction of wear as the clearance is reduced and the diameter increased has clearly been demonstrated.

Extremely low long-term wear rates with minimal bedding-in wear might be achieved by optimising the principal design features (diameter diametral clearance, surface finish) of zirconia-on-metal joints.

REFERENCES