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Appendix

Whole-blood samples were collected in trace element blood tubes (K_2EDTA; Becton, Dickinson, Franklin Lakes, New Jersey) using the Vacutainer system (Becton, Dickinson). These trace element tubes are certified low for metals. This system uses a stainless-steel needle containing 11% Cr and no Co. Unpublished data showed there was no measurable metal contamination from the stainless-steel needle. Samples were anonymized and stored at −20°C. Standard operating procedures were established for Co and Cr measurement in biologic fluids using dynamic reaction cell inductively coupled plasma mass spectrometry (DRC IC-PMS) (ELAN DRC II; PerkinElmer, Waltham, Massachusetts). This took place in a laboratory that is one of the seven Trace Element Quality Assurance Service (TEQAS) laboratories in the U.K. Forty-four of the 138 recruited patients did not have prerevision blood metal ion measurement. The absence of this test was due to the surgeon who referred the patient's implant and associated data rather than due to any specific selection criteria.

Wear Analysis

The linear wear of the heads and cups was measured with use of a Talyrond 365 roundness machine (Taylor Hobson, Leicester, United Kingdom). A stylus (2-mm-diameter ruby) contacts the surface of component as it is rotated on a high accuracy spindle (±0.02 μm) and measures the deviation from a perfect circle (resolution of stylus gauge, 10 nm). The raw profiles were analyzed with use of the Taylor Hobson Ultra Software and in MATLAB (The MathWorks, Natick, Massachusetts). The linear wear rate in micrometers per year was calculated by dividing the maximum linear wear depth by the time implanted.

The cup surfaces were measured in two planes. A series of circumferential profiles were taken at 1-mm increments along the lines of latitude, and a series of polar profiles were taken along the lines of longitude through the pole of the component and at right angles to the circumferential profiles. A best-fit circle or arc was fitted through each profile to represent the unworn shape of the component, and the maximum linear wear was calculated from the maximum deviation from the best-fit circle to the measured profile. By analyzing the data from both measurements, it is possible to separate the in vivo wear from the manufactured form error. The cup measurement allows the position and extent of the wear scar to be calculated; cups were classified as being edge-loaded if the maximum linear depth of the wear scar occurred at the rim of the cup.

The heads were measured in a series of twelve polar profiles along lines of latitude. To separate the wear from form errors, the profiles were plotted on the same axis, which allowed the deviation between worn and unworn sections of the profile to be calculated. Using this method, it is possible to identify wear scars of <1 μm deep on heads with >20 μm form error.

Edge-Loading

This method also allowed the position and extent of the wear patch to be measured as well as the maximum depth, therefore identifying edge-loaded acetabular components. Cups were identified as being edge-loaded (or edge worn) if the maximum linear wear depth occurred at the rim of the cup. This occurs as a result of the contact patch between the cup and head extending over the rim[7] to an extent where the maximum contact pressure is exerted at the cup edge. Cups demonstrating a wear patch that intersected the cup edge but did not exhibit maximum linear wear at the rim were not classified as edge-loaded.

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TABLE E-1 Univariate Analysis (Linear Regression) of Individual Variables Related to the Outcome Log Head Wear Rate of 138 Cup Components

Variable Compared with Log Cup Wear Rate	Coefficient	Lower 95% Confidence Interval	Upper 95% Confidence Interval	P Value
Blood cobalt levels *(ppb)*	0.019	0.013	0.025	<0.0001
Blood chromium levels *(ppb)*	0.016	0.009	0.023	<0.0001
Cup edge worn *(Y/N)*	1.25	0.9	1.6	<0.0001
Cup inclination angle *(deg)*	0.032	0.015	0.048	<0.0001
Resurfacing or stemmed	−0.28	−0.66	0.09	0.14
Sex *(F/M)*	−0.11	−0.50	0.28	0.59
Head size *(mm)*	−0.005	−0.05	0.039	0.08
Months implanted	0.005	−0.004	0.013	0.31
Unexplained vs. aseptic loosening	0.03	−0.54	0.6	0.092
Unexplained vs. infection	−0.42	−0.22	1.2	0.16
Unexplained vs. other	0.50	−0.22	1.21	0.18
BHR vs. Cormet	−0.05	−0.52	0.43	0.85
BHR vs. ASR	0.15	−0.3	0.6	0.52
BHR vs. other	−0.77	−1.3	−0.24	0.004

TABLE E-2 The Final ANCOVA Multivariate Statistical Models for Log Head Wear Rate

Variable Compared with Log Cup Wear Rate	Coefficient	Lower 95% Confidence Interval	Upper 95% Confidence Interval	P Value
Cup edge worn				
True*	–	–	–	–
False	−1.1	−1.6	−0.65	<0.0001
Cause of failure				
Unexplained*	–	–	–	–
Aseptic loosening	−0.63	−1.3	−0.002	0.049
Infection	−0.28	−0.93	0.38	0.4
Other	0.45	−0.3	1.2	0.24
Blood cobalt *(ppb)*	0.01	0.008	0.02	<0.0001
Cup edge loaded × cause of failure = aseptic loosening	1.7	0.51	2.81	0.005
Cup edge loaded × cause of failure = infection	−0.35	−1.44	0.75	0.53
Cup edge loaded × cause of failure = other	0.39	−0.75	1.54	0.50

*Baseline for categorical variable.