In vivo Wear of a Squeaky Alumina-on-Alumina Hip Prosthesis

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Introduction: Lately, there have been anecdotal reports of squeaking in ceramic-on-ceramic (COC) joints. Although reported as uncommon in a recent study [1], squeaking of COC joints warrants investigation as it may signal abnormal wear of the bearing surfaces, which can become a runaway process with ceramics. In this study, we had the opportunity to examine an alumina-on-alumina hip that was explanted because of persistent squeaking. We hypothesized that the squeaking was associated with degradation of the bearing surfaces. We also sought to establish the cause of any such degradation.

Materials and Methods: A sixty-four-year-old male underwent primary total hip replacement surgery on the left hip for treatment of end-stage osteoarthritis. A Trident ceramic hip (Stryker Corp., Kalamazoo, MI) with a 28 mm diameter head was implanted through an anterolateral approach. In this implant, an alumina ball articulates against a titanium alloy-backed alumina cup insert. The alumina is BioLox Forte (CeramTec AG, Plochingen, Germany). The hip was revised after 32 months because the patient experienced severe audible squeaking in his hip with all activity. The cup inclination angle measured from a frontal plane radiograph was 68°. The surfaces were examined with a stereomicroscope and with a Leo Gemini 1530 field emission SEM. Surface roughness measurements of the articular surfaces were performed with a Zygo NewView 6300 white light interferometry microscope using a 20 X Mirau objective. Metrology measurements to determine wear patterns and estimate total wear on the head and the cup were performed with the SmartScope Flash coordinate measuring machine (CMM) using a method developed previously [2]. This CMM has a measurement precision of 2 μm in the x-y plane and 3 μm in the z direction.

Results: Photographs of the head and cup are shown in Fig. 1. Immediately visible on the head are three dark streaks, the largest being 14 mm x 1 mm, with one end close to the pole. Examination by SEM-EDX revealed the streaks to be smeared titanium-containing material, consistent with evidence of impingement found on the inner side of the overhanging edge of the titanium alloy backing. On closer visual examination, large slightly matted areas were found on both the head and the cup. The areas are highlighted with a green tint in Fig. 1.

It is of interest that the largest metal streak spans almost exactly the wear band on the head. The surface roughness of the dulled area on the head near the pole was 133 nm Ra versus 3.8 nm Ra in a nearby still polished area. This considerable difference was reflected in the appearance of these surfaces under SEM examination. The grain structure was clearly visible for both surfaces, but grain pullout and fracture were far more extensive in the roughened area (Fig. 2). The metrology scan of the bearing surfaces revealed substantial deviations from the original hemisphere, yielding the wear maps shown in Fig. 3. The high deviations areas matched the wear scars (Fig. 1). Head and cup penetration values were 85 and 120 μm, respectively, corresponding to annualized penetration values of 32 and 45 μm/yr.

Discussion: Surprisingly, there was no evidence of stripe wear or of head impact against the edge of the ceramic insert and the observed wear features are unrelated to previously reported micro-separation of COC joints. Still, the head and cup penetration values in this study significantly exceed those reported for well-functioning alumina-on-alumina joints (<5 μm/yr) [3]. They are higher than the average values of 25 and 17 μm/yr (head, cup) for stripe wear but lower than the average values of 246 and 162 μm/yr for severe wear calculated from data reported for a set of 10 Mittelmeier Autophor alumina-on-alumina hip prostheses explanted for revision [4]. The steep inclination angle (68°) of the cup led to some degree of edge loading against the head, which increased the contact stresses and consequently the wear rate. In a recent study [1], cup orientation and edge loading were reported as factors contributing to squeaking in ceramic-on-ceramic hips. The steep inclination angle also appears to have led to subluxation of the head, leading to contact with the metal backing overhang, and smearing of metal on the articular surface. The position of the large metal smear across the wear band on the head (Fig. 1, left), suggests the smear is directly connected with the abnormal wear pattern. It is speculated that the metal smear reduced the fluid lubrication of the joint during its flexion-extension sweeps, leading to higher wear and surface roughening. The squeaking sound may then result from stick-slip of the roughened surfaces against each other under load. It may be concluded that the squeaking sound made by the joint was associated with degradation of the bearing surfaces. The hypothesis that squeaking in COC joints may provide an early warning signal of joint degradation should be further investigated.