Neck Impingement Testing of a Novel Hard on Hard Hip Bearing

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Purpose: A new composition of oxidized Zr-2.5 wt%Nb alloy (DHOxZr) with increased depth of hardening has been developed [1]. This novel material is suitable for hard-on-hard articulation in total hip arthroplasty (THA) with low wear and no risk of brittle failure. Suboptimal implant positioning may result in intraprosthetic impingement between the femoral neck and acetabular liner or socket resulting in implant damage [2,3]. The goal of this study was to evaluate the performance of DHOxZr bearings under impingement conditions.

Methods: DHOxZr femoral heads (32 mm) and acetabular liners were machined from Zr-2.5Nb alloy, oxidized, diffusion-hardened, and polished (n=3); this size couple was selected as it represents the smallest range of motion and head-to-neck ratio of DHOxZr bearings. Identically sized alumina ceramic bearings were chosen as controls (n=2). Neck impingement testing was performed per ASTM 2582-08, Standard Test Method for Impingement of Acetabular Prostheses (Figure 1). Static dislocation was performed on one couple from each group at room temperature with a load rate of 5°/min and each couple lightly coated with distilled water. Static dislocation values were used to determine unidirectional dynamic impingement inputs of 5.4 Nm max (3.7 Nm min) and 3.7 Nm max (2.2 Nm min) for alumina and DHOxZr couples, respectively. Components were tested at 1 Hz for 1 million cycles (Mcycle) using water as the lubricant; angular displacement of the liner was collected every 1000 cycles. Upon completion of testing, all components were marked to show impingement, and examined visually and with a SEM.

Figure 1: ASTM 2582:08 Neck impingement fixture

Results: All constructs completed 1 Mcycle of testing without failure. Average change in maximum angular displacement over 1 Mcycle was 0.34° and 0.12° for alumina and DHOxZr couples, respectively (Figure 2); this difference was not statistically significant ($p = 0.1$). Evidence of impingement was noted on all femoral necks (Figure 3). Alumina and DHOxZr liners revealed Titanium transfer was observed at the rim of all liners (Figure 4); on the two DHOxZr liners tested exclusively under dynamic impingement, this transfer was observed only when examined by SEM/EDAX. Alumina liners exhibited grain pullout at the point of neck impingement. DHOxZr liners exhibited localized microscopic cracking of the oxide at the point of neck impingement. No delamination of the oxide was observed, and micro-cracking was contained to the area of impingement. This

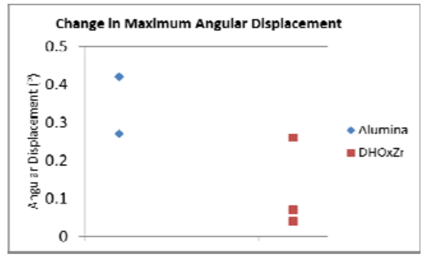

Figure 2: Change in max angular displacement

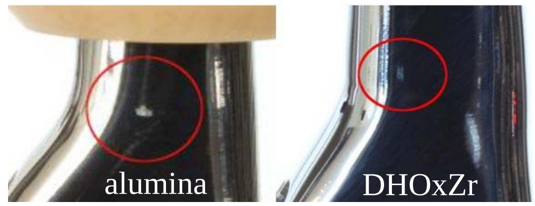

Figure 3: Representative femoral neck damage from static impingement and femoral head subluxation.

type of microscopic cracking, expected with high contact stress and deformation of the substrate, is not indicative of bearing failure and does not increase wear [5,6].

Conclusions: Liner movement within the shell was lower for DHOxZr than alumina when tested per ASTM 2582-08, potentially due to a more conformal taper lock. The combination of lower bulk modulus and high surface hardness of the DHOxZr material provides a stress relief mechanism unavailable to monolithic ceramics. In contrast, such localized stress concentrations can cause brittle fracture in ceramics [2-4]. **S**ample size and less extreme impingement loads are recognized as limitations of the current study. Although loads applied per the ASTM standard likely underestimate in-vivo loads, data is still valuable comparative purposes. DHOxZr bearings may tolerate impingement loading better than ceramics; additional testing with anatomic loads may further improve understanding of damage resistance.

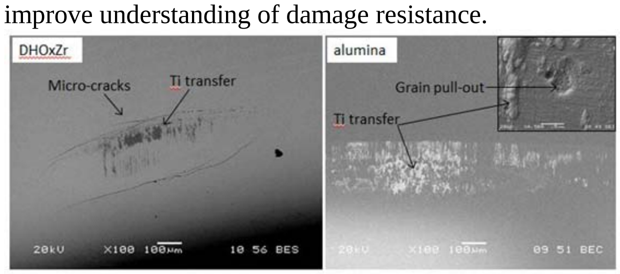

Figure 4: SEM images of neck impingement; darker colored areas on left and lighter colored areas on right are Ti6Al4V transfer.

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References: [1] Pawar et al, App Surf Science, 257, 2011 [2] Elkins et al, JOA, 27, 2012 [3] Lee et al, J Orthop Res, 29, 2011 [4] Morlock et al, Total Hip Arthroplasty, EFORT, 3-16, 2013 [5] Parikh et al, ORS, 1156, 2011 [6] Parikh et al, ORS, 1817, 2014