The Influence of Roughness on the Wettability of Retrieved Cobalt-Chromium and Zirconia Femoral Heads

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Introduction: The purpose of this study was to evaluate the effects of surface roughness and age *in vivo* on surface energy, as measured by contact angle, of retrieved cobalt-chromium alloy (CoCr), yttria-stabilized zirconia (Y-TZP), and magnesia-stabilized zirconia (Mg-PSZ) femoral heads. A lower contact angle corresponds to higher wettability and enhanced lubrication, which should lead to decreased wear *in vivo* [1]. An inverse relationship was hypothesized between contact angle and root-mean-square (RMS) roughness (Sq), which tends to be more sensitive to scratches that could help flatten a water droplet. Because the hardness of CoCr is lower than ceramics, CoCr heads were expected to scratch and roughen more easily [2], and thus contact angle was expected to increase with age. The roughening of Y-TZP with age *in vivo* is well-documented [3-7], while Mg-PSZ does not roughen with age [3], so contact angle was expected to increase with age *in vivo* for only Y-TZP zirconia heads.

Materials and Methods: CoCr (n = 16), Y-TZP (n = 18), and Mg-PSZ (n = 17) femoral heads were retrieved from total hip arthroplasty revision surgeries. Never-implanted control specimens (n = 4-5 each) were donated by Whiteside Biomechanics, Inc. Retrievals were cleaned with a bleach solution and thoroughly rinsed with water and ethanol. Average (Sa) and RMS (Sq) roughness was measured by optical profilometry at magnifications of 32x and 10x, at three locations per specimen. Wettability was measured by the sessile drop method as the average contact angle formed by a 0.25 µL droplet of distilled water [1,8], after methanol, acetone, and alcohol washes [1]. Retrievals were re-measured after washing in enzymatic detergent and rinsing in distilled water. Only the final 10 of 20 droplets per specimen were analyzed to minimize the influence of residual organic material [8]. Roughness and contact angle data were correlated to age *in vivo* and to each other, with $p < 0.05$ for significance. Contact angle data were also compared via t-tests.

Results and Discussion: The roughness of CoCr heads linearly increased with age ($p < 0.01$ at 32x, $p < 0.05$ at 10x), mainly due to the three oldest CoCr retrievals (Figure 1). As before, the roughness of Y-TZP heads increased exponentially with age *in vivo* ($p < 0.001$ at 32x and 10x), while Mg-PSZ did not roughen with age [3].

For all three material types, contact angle after both wash methods was not significantly correlated to age *in vivo* or to surface roughness, even using the most conservative measure of roughness (Sq at 10x, representing an area of 633 µm x 476 µm, slightly smaller than a droplet's footprint). For hydrophilic surfaces, contact angle is inversely proportional to surface roughness via Young's equation [8,9], but the range of roughness measurements was probably too small to produce significant differences.

After averaging all contact angle data by material type (Table 1), the contact angle of retrievals (post-alcohol wash) was significantly lower than corresponding never-implanted controls (unpaired t-test), but increased significantly after enzymatic washing (paired t-test). After the enzymatic wash, only the CoCr retrievals exhibited a contact angle significantly lower than controls, suggesting that the wash at least partially removed a residual film leftover from joint fluid *in vivo*. Because contact angle was not correlated to aging *in vivo*, the data imply that this film is created within weeks of implantation, with material surface chemistry only affecting how fast or perhaps how strongly the film is formed. The CoCr contact angle data suggest that the enzymatic wash incompletely removed the residual film, but differences may have also been due to the various ASTM standards for CoCr among the eight implant companies represented.

Conclusions: To the best of the authors' knowledge, this is the first study to measure the contact angle of retrieved femoral heads. The apparent residual film removed by enzymatic washing implies that joint fluid helps increase the wettability of the bearing surface regardless of substrate material used. Future studies will attempt to recreate this residual film on never-implanted specimens.

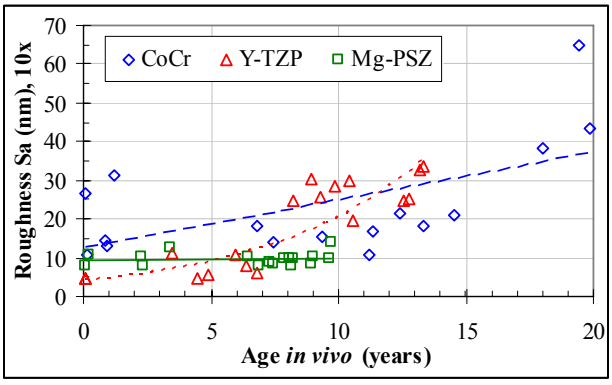

Figure 1. Average roughness data for CoCr (dashed line), Y-TZP (dotted line), and Mg-PSZ retrievals (solid line).

Table 1. Summary of contact angle data (average ± S.D.).

Material	Controls (not implanted)	Retrievals (wash method):	
		Alcohol	Enzyme
CoCr	93.0º ± 1.0º	81.3º ± 6.0º	89.2º ± 3.1º
Y-TZP	83.4º ± 2.9º	73.1º ± 8.5º	81.4º ± 2.9º
Mg-PSZ	78.6º ± 3.2º	72.7º ± 7.0º	79.5º ± 4.0º

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