

A 6 MILLION CYCLE WEAR STUDY OF SILICON NITRIDE AND COBALT CHROME
FEMORAL HEADS ON UHMWPE LINERS

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Statement of Purpose: Clinical and laboratory studies have reported 50 % wear reductions for UHMWPE liners articulating against ceramic femoral heads compared to Co-Cr [1,2]. Silicon nitride (SiN) offers improved flexural strength and fracture toughness compared to alumina. However, the wear performance of SiN against UHMWPE has yet to be reported. Therefore, the aim of the current study was to test the hypothesis that SiN femoral heads would create lower UHMWPE wear in comparison to Co-Cr heads.

Methods: Six isostatically moulded UHMWPE hip liners (28 mm) were studied (Biomet Inc, IN). All liners were γ -sterilized (25–40 kGy, argon). The UHMWPE liners were either coupled with Co-Cr (Biomet Inc, Warsaw, US) or SiN heads (Amedica-Inc, Salt Lake City, Utah, US). The initial surface roughness (Ra) for Co-Cr and SiN heads was 4–12 nm. Liners were positioned inverted in a 9-station orbital hip joint simulator [Shore-Western, US]. Test duration was 6.5 million cycles (Mc) of walking. The lubricant was alpha-calf serum, 20 mg/ml protein (HyClone). Liner wear was measured gravimetrically, and was adjusted using loaded soak controls. Surface roughness of all components was measured at 0, 1, 3 and 5 Mc (New View 5000, Zygo).

Results: The wear trends appeared linear for all UHMWPE liners up to 6.5 Mc ($r>0.9$), averaging 15.5 and 16 mm³/Mc for the Co-Cr and SiN groups ($p>0.05$), respectively (Figure 1). The Co-Cr temperature profile showed consistently 4 degrees higher serum temperature compared to SiN heads (Figure 2).

All femoral heads showed increased surface roughness following wear. At 5 Mc, the Co-Cr and SiN roughness peaked at 410 and 24 nm, respectively (Table 1). This represented a 17-fold increase in roughness for the Co-Cr heads. For the UHMWPE, at 1 Mc the mean surface roughnesses were 106 and 77 nm with Co-Cr and SiN, respectively (Table 2). At 3 and 5 Mc, there was little difference between groups.

Discussion / Conclusions: This is the first hip simulator study of SiN-on-UHMWPE hip prostheses. Our wear data showed no statistical differences between head groups. However, this outcome may be an underestimation of the true advantage of SiN as a bearing surface. For example, the thermal conductivities of Co-Cr and SiN are 16 and 30 W m⁻¹ K⁻¹, respectively, i.e. 50 % less for Co-Cr. Thus, the Co-Cr heads would run hotter and cause greater protein precipitation. This known effect results in reduced wear of UHMWPE [3,4]. Consistently higher serum temperatures were observed for the Co-Cr stations in our study. Therefore, we concluded that the UHMWPE wear ranking would be indicative of SiN < Co-Cr. Therefore, our hypothesis was proved.

The 17-fold increase in maximum surface roughness (Ra) for the Co-Cr heads at 5 Mc compared to the ceramic

indicates the superior scratch resistance for silicon nitride. As rougher counterfaces have been shown to generate greater numbers of submicron sized particles [5], these results suggest that the use of SiN heads may extend the useful implantation periods of THA compared to the use of Co-Cr.

References: [1] Dowson D., *Wear* 190, 171-183, 1995. [2] Semlitsch and Willert *et al.* *Proc Instn Mech Engrs*, Vol 211, 1997. [3] Wang A. *et al.* *JBMR*, 68(B), 45-52, 2004. [4] Liao *et al.* *JBMR*, 48(4), 465-473, 1999. [5] Bowsher *et al.*, *Trans of ORS*, 2005.

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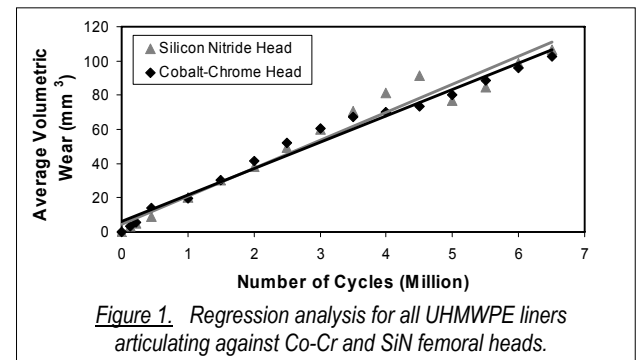


Figure 1. Regression analysis for all UHMWPE liners articulating against Co-Cr and SiN femoral heads.

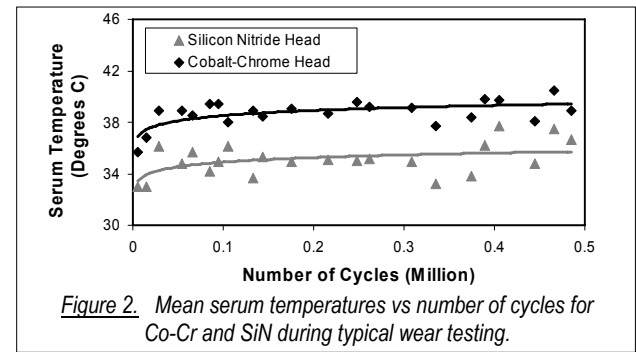


Figure 2. Mean serum temperatures vs number of cycles for Co-Cr and SiN during typical wear testing.

Table 1	Surface Roughness of Femoral Heads (nm)			
	Silicon Nitride Group		Co-Cr Group	
	Mean	Max	Mean	Max
At 1 Mc	4.3	7	8.6	19
At 3 Mc	18	37	101	381
At 5 Mc	15	24	112	410

Table 2	Surface Roughness of UHMWPE Liners (nm)			
	Silicon Nitride Group		Co-Cr Group	
	Mean	Max	Mean	Max
At 1 Mc	77	177	106	276
At 3 Mc	76	177	99	199
At 5 Mc	93	190	102	187