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Which factors determine the volume of material lost from the taper junction of metal-on-metal hip replacements?

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Summary. Multiple linear regression analysis of fifteen factors showed that bearing surface design was the most significant predictor of high taper material loss in retrieved metal-on-metal hip replacements.

Introduction. Joint registries have reported high revision rates for large diameter metal-on-metal total hip replacements (MOM-THR). It has been speculated that additional cobalt-chrome debris may be released from head-stem taper junction, and that this may be implicated in clinical failure. However, the mechanisms and clinical significance of taper material loss remain largely unclear. The purpose of this study was to measure the volume of taper material loss in a large series of MOM-THR retrievals, and then by using multiple linear regression analysis identify any significant predictors of high taper material loss.

Methods. This was a retrospective study of 125 consecutively collected large diameter ($\geq$ 38mm) MOM retrieval cases, and included six contemporary bearing designs and eight femoral stem designs. We recorded patient demographic data and all commonly reported clinical and design variables, including fifteen variables identified through review of the literature that had been indicated as factors likely to affect the mechanical or electrochemical properties of the head-stem taper junction (Table 1). Post-operatively we measured the volume of material lost from all 280 components. Material loss of the bearing surfaces was measured using a coordinate measuring machine and of the taper surfaces using a roundness measuring machine. We then performed univariable and multiple linear regression analyses to determine the variables significantly associated with high volumes of material loss at the taper junction.

Results. The median volume of material loss from the taper junction was 2.16mm^3 (range: 0.13 - 25.19), significantly ($p < 0.001$) less than the median volume of material lost from the bearing surface, which was 5.79mm^3 (range: 0.59 - 309.17). Full results of all univariable regression analyses are given in Table 1. Univariable analysis identified two significant predictors of high taper material loss: (1) bearing surface design ($p = 0.015$) and (2) edge loading of the bearing surfaces ($p = 0.017$). The same two variables were confirmed as the only two significant predictors in the final multiple linear regression model (Table 2), and both were independent predictors, with tests for interaction proving non-significant ($p = 0.510$).

Discussion/Conclusion. It has been speculated that material loss at the head-stem taper junction is implicated in the high revision rates reported for MOM-THR. However, there is little published data to support this and both the clinical significance and mechanism of material loss remains poorly understood. Using multivariable statistical analysis to analyze a large series of retrieval data, we have shown that bearing surface design and edge loading of the bearing surfaces are significant predictors for high taper material loss. This study contributes significantly to our understanding of the mechanisms of MOM hip failure, and suggests important factors that predispose patients to increased metal ion exposure.

Table 1. Summary of the univariable associations between the fifteen studied predictor variables and taper material loss. Estimated effect sizes represent the relative change in taper material loss for a unit increase in the predictor variable. Significant predictors of taper material loss are shown in red.

	Beta Coefficient	Estimated Effect	95% Confidence Interval	P-value	R^2
Patient Age (years)	0.003	1.003	0.97 - 1.03	0.802	0.11%
Gender (F: M)	-0.026	0.974	0.54 - 1.74	0.927	0.01%
Cup Inclination angle (°)	0.005	1.005	0.97 - 1.03	0.742	0.19%
Cup Version angle (°)	0.012	1.012	0.99 - 1.03	0.214	2.96%
Femoral Diameter (mm)	0.046	1.047	0.98 -1.11	0.131	3.83%
Horizontal Femoral Offset (mm)	0.006	1.006	0.95 - 1.06	0.823	0.16%
Vertical Femoral Offset (mm)	0.014	1.015	0.94 - 1.04	0.225	2.11%
Geometric Taper Offset (mm)	0.009	1.009	0.95 – 1.10	0.190	2.64%
Head-Cup Clearance (μm)	0.006	1.006	0.88 - 1.14	0.926	0.01%
Taper Engagement Length (mm)	-0.007	0.993	0.91 - 1.07	0.862	0.05%
Bearing Surface Design	**0.750**	**2.117**	**1.16 - 3.86**	**0.015**	**9.58%**
Stem Design	0.004	1.004	0.89 – 1.01	0.980	0.01%
Stem Material (CoCr : Ti)	0.251	1.285	0.67 - 2.45	0.434	1.04%
Total Bearing Surface Wear (mm^3)	0.004	1.004	0.99 - 1.00	0.162	3.29%
Edge Loading	**-0.695**	**0.499**	**0.28 - 0.87**	**0.017**	**9.31%**

Table 2. Final multiple linear regression model showing the two remaining significant predictors of high taper material loss: (1) bearing surface design, and (2) edge loading

	Beta Coefficient	Estimated Effect	95% Confidence Interval	P-value
Bearing Surface Design	0.624	1.866	1.03-3.39	0.041
Edge Loading	-0.574	0.563	0.32-0.99	0.045