INTRODUCTION:
Most total hip replacement operations are very successful procedures. Typically a hip prosthesis consists of a cobalt chrome femoral head which articulates within a polymeric acetabular cup. The majority of hip prostheses fail due to aseptic loosening, which is considered to be the body’s reaction to polyethylene wear debris. Therefore one way to remove this problem is to replace the polyethylene with a harder material such as cobalt chrome, to give a metal-on-metal (MoM) articulation. Clinical results for such MoM hip prostheses are generally positive and similar encouraging results are also reported from in vitro studies [1]. In these laboratory tests ‘self-polishing’ of the articulating surfaces of test prostheses has been reported [2]. Self-polishing describes a beneficial process in which surfaces become smoother through the process of articulating against each other. Therefore self-polishing can also be tied in with a ‘bedding in’ period. Self-polishing has been claimed from explanted hip prostheses but these assertions are based on qualitative rather than quantitative data [3-5].

METHODS:
Two MoM total hip prostheses, consisting of femoral head and acetabular cup, of 36mm nominal articulating diameter, were obtained at revision surgery (figure 1). The explants were examined using a ZYGO NewView 5000 non-contacting profilometer. This device allowed measurements of surface roughness to be obtained and these were taken at a range of positions on the explanted heads and cups. A minimum of 165 readings were taken per component. Roughness was measured in terms of Ra (roughness average) and Rsk (skewness). In addition the spherical diameters of each head and cup were measured using a Mitutoyo 544 co-ordinate measuring machine. From these measurements, together with knowing the material properties of cobalt chrome and typical operating conditions for a total hip replacement the minimum effective film thickness and thus the lambda ratio was calculated for the total hip replacement when new, based on the ‘unworn’ area, and for the ‘worn’ area using the following equations [6]:

\[ h_{\text{min}} = \frac{2.80}{R_{e}} \left( \frac{\eta u}{E^* R_{e}} \right)^{0.69} \left( \frac{w}{E^* R_{e}} \right)^{-0.21} \lambda \approx \frac{h_{\text{seg}}}{R_{e2}} + \left( R_{e2} \right)^2 \]

In the above equations, \( h_{\text{seg}} \) is the minimum effective film thickness (m), \( R_{e} \) is the effective radius (m), \( \eta \) is the lubricant viscosity (Pa s), \( u \) is the entraining velocity (m/s), \( E^* \) is the equivalent elastic modulus (Pa), \( w \) is the load (N), \( \lambda \) is the lambda ratio, and \( R_{e1} \) and \( R_{e2} \) are the roughness values of the femoral head and acetabular cup.

RESULTS:
The roughness data indicated that, in the ‘worn’ (figure 2) areas, Ra values were reduced compared with ‘unworn’ (figure 3) parts of the articulating surfaces of the explants. Typical values were 0.006µm Ra and 0.020µm Ra respectively. In addition the Rsk values were negative in the ‘worn’ areas compared with positive in the ‘unworn’ areas. Using the measured data allowed lambda ratios of 0.9 (boundary lubrication) for the ‘unworn’ area, and 3.0 (mild mixed lubrication) in the ‘worn’ area to be calculated.

Fig. 1: The femoral head (left) and acetabular cup (right) from one of the explanted total hip replacements.

Fig. 2: Typical topography of ‘worn’ region of explant. Note lack of localized peaks, multi-directional scratches and Ra value of 0.003µm.

Fig. 3: Typical topography of ‘unworn’ region of explant. Note localized peaks, lack of scratches and Ra value of 0.015µm.

DISCUSSION:
To the authors’ best knowledge this is the first time that quantitative data related to the surface topography of explanted MoM total hip replacements has been offered which supports the concept of self-polishing in vivo. While other papers have offered this opinion, Milosev et al [4] only offered Ra data for femoral components, and both Milosev et al [4] and Reinisch et al [5] reported on components that had high (0.1-0.15µm and 0.07µm respectively) Ra values in both ‘worn’ and ‘unworn’ areas. In addition the skewness values reported here show that the surface has changed from one with a majority of peaks (positive Rsk) to one with a majority of ‘valleys’ (negative Rsk). The lambda ratios also indicate that these prostheses, when ‘worn’ would have operated in the benign mild mixed lubrication regime, a useful improvement on the lower initial lambda ratios.

REFERENCES: