INTRODUCTION:
There is a large variation in the clinical wear rates and ion levels among patients with metal-on-metal hip surface replacements. High wear and outlier ion levels have been primarily associated with edge-loading, when the femoral ball comes into contact with the edge of the cup. Although edge loading is associated with high cup inclination angles, there are several other potential causes, including separation caused by insufficient head offset and joint laxity. Two different hip simulator models have been proposed to replicate clinical edge-loading; one with increased cup angle and one with microseparation [1]. The aim of this study was to determine which of these two experimental methods best replicates the wear and wear patterns seen on clinically retrieved components.

METHODS:
This study investigated the acetabular components (cup) of surface replacements (ASR\textsuperscript{TM}, DePuy International, Leeds, UK) that had undergone three different treatments: 1) Clinical use in patients with edge-loading (n=6). 2) Hip simulator testing with high cup inclination angle (n=5) and 3) Hip simulator testing with microseparation (n=5). Six clinically retrieved edge-loaded cups were available for analysis, with diameters ranging from 40 to 54mm, duration in vivo from 6 to 24 months and implantation angles from 35° to 75°. The cups were classified as edge-loaded if there was maximum wear depth penetration at the edge.

Surface replacements with a bearing diameter of 39mm were investigated in two different hip simulator studies. The high cup angle samples were tested in a Prosim hip simulator (Sim Solutions, Stockport, UK) with a cup inclination angle of 60°. The microseparation samples were tested in a Leeds Mark II Hip Simulator (Leeds, UK) for 2 million cycles as described previously [1]. Wear was measured using a Coordinate measurement machine (CMM, Mitutoyo). CMM dimensional wear measurements on the hip simulator samples were compared to gravimetric data obtained previously to determine the validity of the method.

A field emission scanning electron microscope (FEGSEM) (Carl Zeiss Inc) was used to investigate the worn surfaces. Images were taken every 1mm around the edge of the cup within the wear area, at a magnification of 650X. Ten images were then taken at 2mm spacing across the middle of the wear area for comparison to the edge of the cup. The SEM images were then scored according to the size of the damage space present (Fig. 1) and plotted on a map of the sample to give an idea of the location of the damage. The orientation of the damage patterns were measured relative to a tangent to the edge of the cup. Statistics: Differences between the three different groups were evaluated by one-way ANOVA, with Fisher’s least significant difference (LSD) post-hoc testing to determine individual p-values.

RESULTS:
Wear rates: For the simulator samples, the values of wear as measured by CMM were within 10% of those measured by weight loss and strongly correlated ($R^2=0.98$), validating the CMM method. The mean wear rates of the edge-loaded clinical retrievals and simulator samples were similar (11.7mm/year for retrievals, 11.6 mm/2 million cycles for high cup simulator samples and 13.6mm/2 million cycles for microseparation samples). However, there was a very large distribution in the wear rates of the edge loaded retrieved components (St Dev = 15.58mm$^3$) making it difficult to draw any firm conclusions.

Elongated pits in the size range 2-100µm were present in a band located 0.05 to 1mm from edge of the cups. (Fig. 1). Mapping of the surfaces of all of the edge-loading retrievals confirmed that this form of damage was present almost exclusively at the edge, and was most common in the middle of the wear area at the point of maximum wear (Fig. 1). Similar elongated pits were also observed on both the microseparation and the high cup angle simulator components. The larger pits (20-100µm) were similar in incidence in the retrieved and microseparation components (p=0.18), but, were less common in the high cup angle components (p=0.02). On the retrieved components, the pits were orientated approximately perpendicular to the edge of the cup (mean angle 73°). On the microseparation components, the pits were in a similar orientation (mean angle 73°, p=0.11) while, on the high cup components, the pits were orientated closer to parallel relative to the edge (mean angle 13°, p=0.0001) (Fig. 2).

DISCUSSION:
The results of this study suggest 1) that microseparation hip simulator studies replicate clinical edge-loading wear patterns better than high cup angle hip simulation and 2) that clinically the femoral component moves laterally over the edge of the cup (micro separates) supporting the findings of fluoroscopy studies [2]. It is hypothesized that microseparation is controlled clinically by head position and soft tissue tension. This study has also found an unusual wear mechanism to be occurring at the edge of these edge-loading components. It is hypothesized that the particles produced could be larger than produced under standard conditions and, therefore, elicit different host responses.

REFERENCES:

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