The Relationship Between in vivo Joint Reaction Force and Wear Scar Location in failed Metal-on-Metal Hip Implants

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Disclosures:

Introduction: With highly variable loads transferred through the human hip, excess multidirectional force may contribute to osteoarthritis or hip implant failure. Telemetric implants in small groups of patients have been used to measure loads through the hip in 3 dimensions. Increasing acetabular inclination has been shown to lead to increased acetabular wear and “edge loading”, showing quantitative wear behaviour in metal-on-metal (MoM) hip implants. However, 3D wear scar location and hip and abductor force magnitude have not yet been investigated, and qualitative wear patterns remain largely unknown. This study’s hypothesis was, therefore, that there is a positive correlation between the hip joint reaction and abductor forces and the wear angle in retrieved MoM hip implants.

Methods: A database of patients with failed MoM hip resurfacings was gathered (n=11). Using 3D CT and appropriate software, a 3D image of each pelvis was generated. An out-of-roundness machine was used to localise the epicentre of the primary wear scar (WS1) in each explanted acetabular cup and this was then co-registered with its in vivo location. The WS1 vector was drawn, and the wear angle was measured. A free body diagram was modelled and resolved to find the resultant abductor and hip joint reaction forces during the stance phase of walking for each of the 11 patients (see Figure 1 for a two dimensional schematic representation of the method). Along with mathematical modelling, an existing database of in vivo telemetric data was used to do these calculations. Under the recommendation of a bio-statistician, the Pearson’s correlation was calculated between the resultant hip joint reaction force and wear angle and also between the resultant abductor force and wear angle. A result was deemed to be significant at the 5% level (p<0.05). Ethical approval for this study was granted in 2009 by the Integrated Research Application System Research Ethics Committee (number 07/QQ0401/25).

Results: Using the software package, SPSS Statistics, statistical analysis of the results was carried out. The Pearson’s coefficient was calculated to quantify the correlation between the resultant hip joint reaction force and the wear angle, (r²=0.634; p=0.036) and also the correlation between the hip abductor force and the wear angle (r² = 0.611; p=0.046). These results were both statistically significant at the 5% level (Figures 2 & 3). As a negative wear angle represented a WS1 posterior to the centre of the femoral head (COF) and a positive wear angle represented a WS1 anterior to the COF, the more positive the wear angle, the more anterior the wear scar.
Discussion: The results of this study agree with the hypothesis, demonstrating a strong positive correlation between the hip joint reaction and abductor forces and the wear angle in retrieved MoM hip implants. This means that as the hip joint reaction and abductor forces increase, so does the wear angle, and in turn, the three-dimensional location of the WS1 in failed MoM hip implants becomes more anterior with respect to the COF. These findings are not consistent with the current theory of “edge loading”, as in order for a wear vector to exit the cup at its edge, the wear angle needs to be large, regardless of whether the wear scar vector leaves the cup anteriorly or posteriorly. This suggests that perhaps it is the contact stress in force per area at the acetabular cup, rather than the absolute force across the hip joint that influences the presence of edge loading. This study has enabled us to evaluate the qualitative wear behaviour of MoM hips in vivo, which has not been previously possible in this manner. As this was a pilot study, a sample size was not able to be calculated prior to the study. However, this study can now be used to calculate a sample size for a desired correlation, significance and power for future studies. While the sample size was the major limitation, further studies may wish to evaluate the role that hip joint reaction and hip abductor forces play on the three-dimensional location of multiple wear scars, not just WS1.

Significance: This pilot study has provided a valuable insight into how the biomechanics of the hip may affect the wear properties at the hip joint, enabling clinicians to make thoughtful predictions about the potential risk of failure in their patients with MoM hip implants. Additionally, it may help to identify those who are unsuitable for conventional hip revision surgery due to biomechanical contraindications. The findings of this study may be applied to native hips, as well as those undergoing arthroplasty. As osteoarthritis is often attributed to excess forces through the hip, by being able to predict the manifestations of these forces, i.e. the primary areas of wear, the disease progression and those at risk of developing musculoskeletal pathologies can be identified and appropriately advised.

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