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The Relationship Between The In Vivo Force Acting On A Metal-On-Metal Hip And The Location Of Its Wear Scar: A Novel Retrieval Study Using 3D CT

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Introduction

The human hip joint is important, both in health and disease. Its range of motion is remarkable, and thus the loads transferred through the hip can be highly variable, depending on the patient's activity. Investigation of retrieved hip implants can give us insight into multidirectional forces and its role in implant failure. The current theory of "edge loading" has shown a quantitative relationship between the location of the primary wear scar (WS_1) at the edge and the wear volume.

Methods

Patient selection
- N = 11 (Mean age 51.6 years)
- INCLUDE patients with pre-failure CT scan, body weight and the failed prosthesis available
- EXCLUDE symmetrical acetabular cups i.e. without acetabular fins

***In vivo* force calculation**
- Construct 2D free body diagram (Figure 2)
- Input parameters by measuring them directly or estimating them from pre-existing data of *in vivo* hip joint reaction force (Hip 98)

Retrieval analysis
- Use out-of-roundness machine to create 3D map of acetabular wear
- Note location of WS_1 in relation to acetabular fins

Co-registration
- Generate 3D image of pelvis using 3D CT software (simpleware)
- Match location of WS_1 in explanted cup to its *in vivo* location using acetabular fins as landmark
- Quantify this location by reporting it in terms of wear angle

Figure 1: a flow diagram summarising the method

In vivo joint reaction force calculation

A regression analysis of hip force data (www.ORTHOLOAD.com) was used to find lever arms LLA and GLA for these subjects, assumed equal to those for our retrievals. See below for source of other data. This allowed the 2D Free body force system to be solved for the hip and abductor forces.

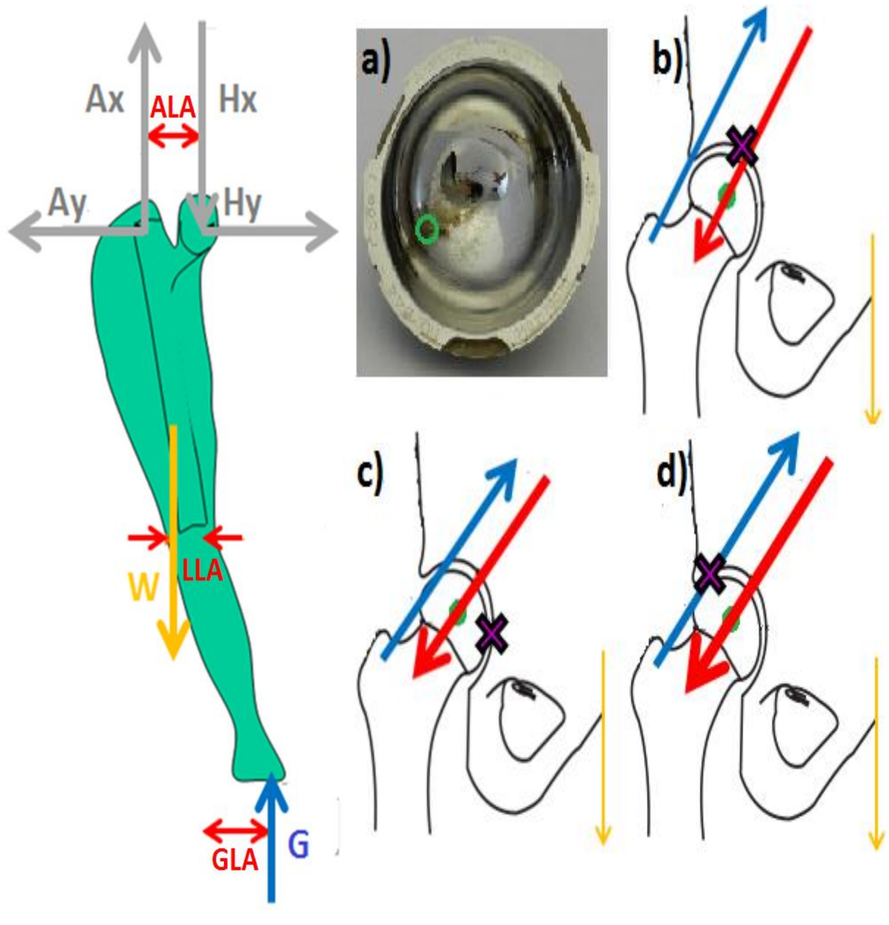

Figure 3 (right): a) photo of retrieved acetabular cup with WS_1 circled in green b-d) schematic representation of the abductor force (blue) hip joint reaction force (red), body weight (yellow) and wear scar (purple) in each patient. b) displays a WS_1 near the hip joint reaction force; c) shows a medial WS_1; d) shows edge wear

Parameter	Definition	Calculation method
Weight (W)	Force exerted on leg due to gravity	1/6th of body weight
Ground reaction force (G)	Force exerted by ground on body	Equals body weight
Abductor angle (AA)	Angle between action of abductor muscles and vertical line through insertion of abductor muscles	Measured on 3D CT
Abductor lever arm (ALA)	Horizontal distance between COF and insertion of abductor muscles	
Leg lever arm (LLA)	Horizontal distance between COF and action of W	Did regression analysis of data from Hip98
Ground lever arm (GLA)	Horizontal distance between COF and action of G	

Figure 2 (above left) & Table 1 (next column): the free body diagram used to calculate the resultant hip joint reaction and abductor forces, and a table explaining the parameters that were used when resolving forces

Results

Using the SPSS Statistics package, the Pearson's correlation was calculated between:

1) The resultant hip joint reaction force and the wear angle
2) The resultant abductor force and the wear angle.

These were 0.634 (p=0.036) and 0.611 (p=0.046) respectively. A negative wear angle represented a WS_1 posterior to the COF and a positive wear angle represented a WS_1 anterior to the COF, hence the more positive the wear angle, the more anterior it was.

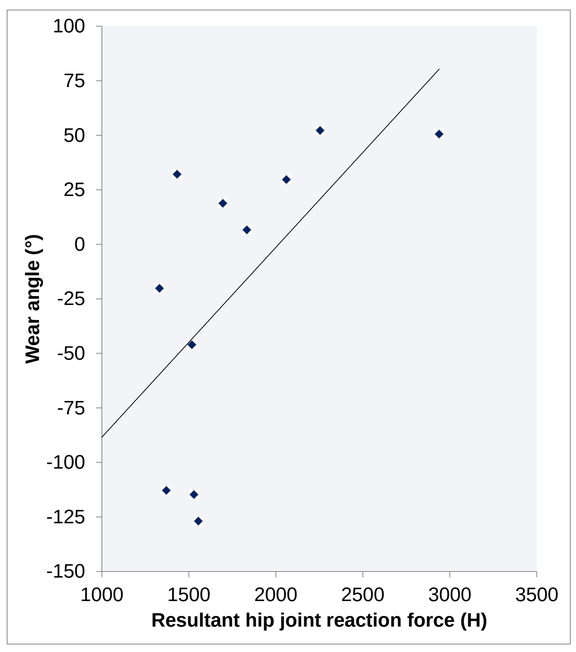

Figure 4: a scatter plot showing the correlation between resultant hip joint reaction force and the wear angle

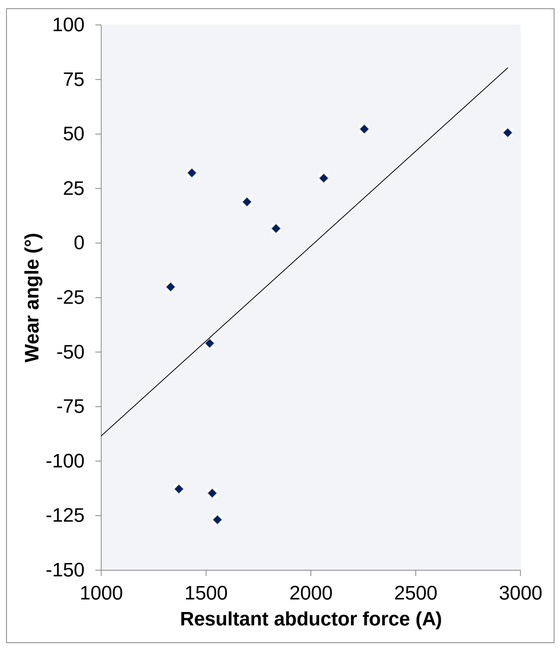

Figure 5: a scatter plot showing the correlation between resultant abductor force and the wear angle

Conclusions

An increase in *in vivo* abductor and hip joint reaction force:
- **does not** lead to edge wear
- results in a **more positive wear angle**
- results in a WS_1 that is **more anterior in the coronal plane**

This pilot study suggests that:
- **anterior wear** may be an important factor in enabling clinicians to make thoughtful predictions about implant failure in patients

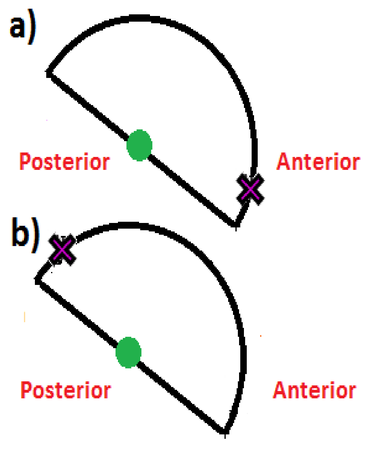

Figure 6: a sagittal view of a schematic diagram of a) a positive wear angle b) a negative wear angle in relation to the COF (in green). Note that the positive wear angle is more anterior