

Initial stability of acetabular cups under physiological conditions: Comparing heel strike to the full gait cycle

*Crosnier, E.A., *Keogh, P.S., *Miles, A.W.

*Centre for Orthopaedic Biomechanics, Department of Mechanical Engineering, University of Bath (UK)

Introduction

The hip joint is subjected to cyclic loading during activities of daily living which can induce micromotion at the bone-implant interface of uncemented acetabular cups. Osseointegration, which is essential for long term implant survival, will occur when micromotion at this interface is below 40 μm and may occur up to 150 μm [1].

To date, studies investigating the micromotion of press-fit cups only report micromotion in one direction. Standard methods also maintain a static cup position throughout testing; usually at the angle of maximum resultant force during gait. Current methods therefore do not take into account the effect of dynamic motion of the hip on micromotion of the cup, nor do they investigate all six degrees of freedom (DoF) of motion.

The aim of this study was to assess press-fit cup micromotion in six DoF under physiological loading when heel strike is modelled compared to walking

Materials and Methods

A cementless acetabular cup (Trident, Stryker) was implanted into polyurethane foam blocks (Sawbones, density=0.48 g/cm³) with a 1 mm press-fit. The blocks were manufactured to replicate important anatomical features of the acetabulum. A six DoF measurement system was rigidly attached to the bottom of the cup through the dome screw hole and micromotion was measured using six LVDT sensors (Figure 1).

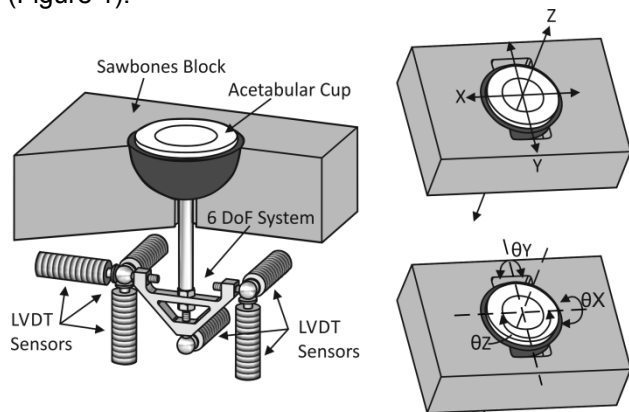


Figure 1 – Six DoF measurement system

The acetabular cup was orientated at 45° inclination. The micromotion of the cup was measured under two conditions: the first represented heel strike with the cup held statically at 30° flexion; the second simulated gait by dynamically flexing and extending the hip (30° flexion to -10° extension; 0.5 Hz) [2]. For all conditions, the cup was cyclically loaded to a peak load of 2.0 kN for 500 steps at 1 Hz. The loading cycles were synchronised with the flexion-

extension movement in order to achieve a loading peak at both simulated heel strike and toe-off positions.

For statistical analysis, Mann-Whitney test were performed ($p < 0.05$).

Results

The X, Y, Z and θY micromotions were significantly greater when the cup was subjected to dynamic motion compared to static heel strike (Figure 2). There were no differences in θX and θZ micromotions. In all cases, the micromotion was less than 150 μm .

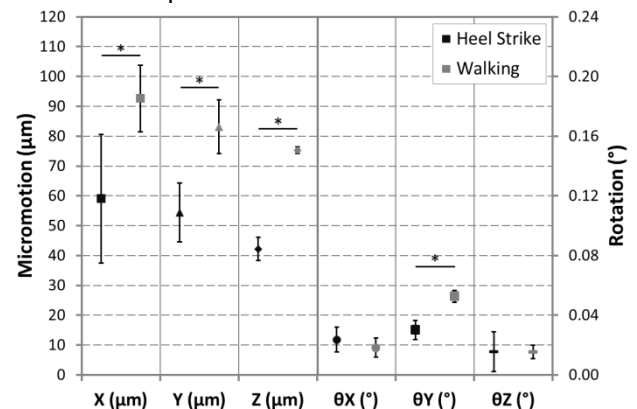


Figure 2 – Micromotion in six DoF of the cup for both heel strike and gait. Values expressed as mean and standard deviation.

Discussion

This study is the first to measure the micromotion in six DoF of a press-fit acetabular cup under both physiological loading conditions and dynamic hip motion. The results indicate that, compared to static tests, the micromotion of the cup increased under dynamic hip motion. The Results also showed that all DoF need to be considered when investigating micromotion of the cup as substantial micromotion was seen in more than one direction.

Conclusion

Future pre-clinical tests investigating micromotion of press-fit acetabular cups should include dynamic motion and measure all DoF of the cup.

References

- [1] Pilliar et al., 1986, Clin. Orthop. Relat. Res., 208
- [2] Bergmann et al., 2001, J. Biomech., 34

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Affiliations

*E.A.Crosnier@bath.ac.uk, Department of Mechanical Engineering, University of Bath, Bath BA2 7AY, UK.