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Six degree of freedom assessment of micromotion of press-fit acetabular cups should be carried out under dynamic hip motion

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Introduction

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

Studies investigating the micromotion of press-fit acetabular cups only report micromotions 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 motion of the hip on micromotion of the cup, nor do they investigate all six degree of freedom (DoF) of motion.

The aim of this study was to assess press-fit cup micromotion in six DoF under physiological loading when the cup is held statically and moved in flexion-extension.

Methods

A cementless acetabular cup (Trident, Stryker) was implanted into polyurethane foam blocks (Sawbones, density = 0.48g/cm³) with a 1mm press-fit. The blocks were manufactured to replicate important anatomical features, which model the acetabulum (Figure 1). 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 2).

The micromotion of the cup was measured under three conditions. Firstly, the cup was tested statically at 30° flexion, representing heel strike during gait; secondly, under dynamic motion simulating gait (30° flexion to -15° extension; 0.5Hz); and finally, under dynamic motion simulating stair climb (45° flexion to -15° extension; 0.5Hz) [2]. For all conditions, the cup was cyclically loaded to a peak load of 2.0kN for 1000 cycles at 1Hz. The loading cycles were synchronised with the flexion-extension movement in order to achieve a loading peak at both heel strike and toe-off positions.

Results

During all of the tests, micromotions in the medial-lateral and anterior-posterior directions, and the resultant of the anterior-posterior tilt, were above 40 µm (Figure 2). When tested statically, the micromotions in the medial-lateral and in the anterior-posterior directions were similar in magnitude. However, when the cup was subjected to dynamic motion, the micromotion in the anterior-posterior direction increased substantially in magnitude. It was at its highest during simulated stair climb. The anterior-posterior tilt also increased substantially under dynamic motion.

Discussion and Conclusions

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 increases under dynamic hip motion. 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. Moving forwards, 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

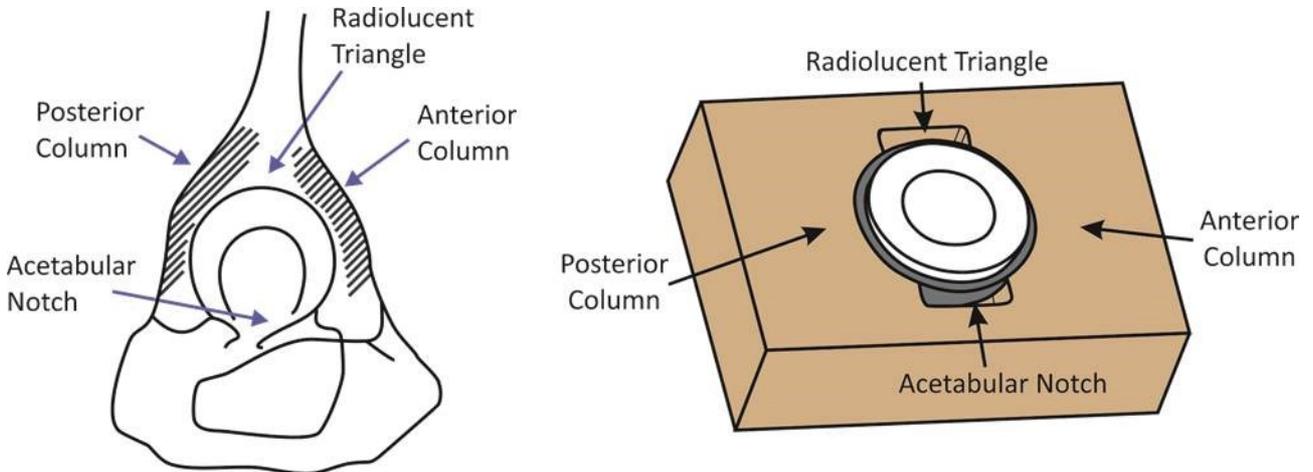


Figure 1 – Important anatomical features of the acetabulum labelled on both the pelvis (left) and the polyurethane foam blocks used in this study (right).

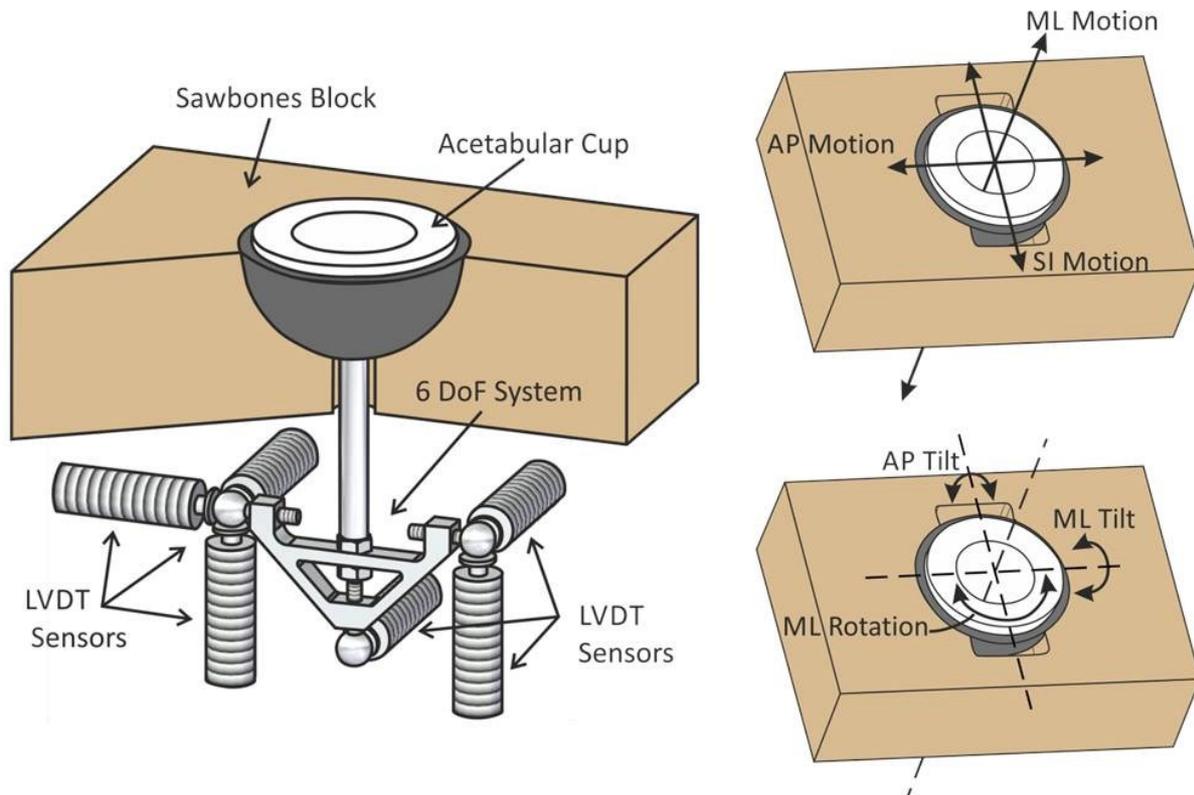


Figure 2 – Left: Setup to measure the six degree of freedom (DoF) of the acetabular cup. Right: 6 DoF of cup (AP = anterior-posterior, ML = medial-lateral, SI = superior-inferior)