CONTACT MECHANICS ANALYSIS AND INITIAL STABILITY OF PRESS-FIT METAL-ON-METAL HIP RESURFACING PROSTHESES

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ABSTRACT
To ensure potential long-term stability and survivorship for metal-on-metal hip resurfacing prostheses, implant migration would need to be minimised to encourage bone in-growth. This study uses the finite element method to investigate the effects of the surgical press-fit procedure on the bearing and interfacial contact mechanics, and on the initial stability of a metal-on-metal (MOM) hip resurfacing prosthesis. The finite element models simulated the press-fit procedure using different amounts of interference between the cup-bone (1-2mm). The resurfacing prosthesis was implanted anatomically into a 3-D bone model. Resultant hip joint loads were applied to the model through muscle and subtrochanteric forces. Results showed that increasing the friction and the interference between the cup and bone resulted in significant reductions in the relative micromotion between the cup and bone. This would ensure the immediate post-operative stability of the acetabular cup and provide adequate conditions for potential long-term bone ingrowth and implant stability. The contact mechanics at the bearing surfaces, which has a large effect on tribological performance, was found to be little affected by changes at the cup-bone interface. These findings are consistent with the general satisfactory short and medium-term clinical results of metal-on-metal hip resurfacing prostheses. This study suggests that interference, friction and a mechanically sound bone structure are important parameters to promote implant stability and support.

INTRODUCTION
Hip resurfacing arthroplasty is regarded as an alternative procedure to total hip arthroplasty, particularly for younger and more active patients, who would likely to undergo a secondary procedure in their lifetime. MOM hip resurfacings offer excellent tribological, clinical and biomechanical advantages [1, 2]. Despite the encouraging medium term clinical reports of these resurfacing devices [3-6], rigorous engineering studies regarding the effects of surgical interfacial parameters on the tribology of the bearing surfaces and implant stability remain largely unavailable. The initial stability of the implant is crucial to its long-term survival and stability. Press-fit cups are used clinically to achieve initial stability, the procedure involves the insertion of an oversized cup into an underreamed acetabular cavity. The cup is held in place by the compressive forces generated by the acetabulum, the resulting minimal micromotion would encourage bone in-growth and ensure long-term implant stability [7, 8]. Studies have recommended using 1-2mm oversized cups, as the amount of oversizing (interference) could affect the initial stability of total hip implants [9, 10]. The purpose this study was to investigate the effect of the surgical press-fit procedure and micromotion on the contact mechanics at the bearing surfaces and on the early stability of the MOM hip resurfacing prosthesis.

METHOD AND MODELS
A 50mm diameter MOM (cobalt chromium) hip resurfacing prosthesis (DUROM™, Zimmer GmbH), with a diametral clearance of 0.145mm was investigated. Three-dimensional finite element models resurfacing prosthesis were created and implanted with a 45° inclination angle and 10° anteversion into 3-D models of the pelvic and femoral bone (Figure 1). Different finite element models were created with varying amounts of interference between the cup and bone (Table 1). Frictionless contact elements were used to model the contact at the bearing surfaces, and a friction coefficient of 0.5 was applied at the cup-bone interface, except where frictionless contact was assumed.
The contact pressure was observed to increase with the amount of interference and friction. This could be due to the increasing resistance to the insertion of the cup by the bone into the acetabular cavity.

The friction and interference, however, had a more significant effect on the relative tangential micromotion between the cup and bone, with a 60% reduction noted when the friction coefficient was increased from 0 to 0.5 for the exact-fit cup models (FE-1 and FE-2). A 90% decrease in micromotion was noted when 1mm interference (FE-3) was applied to the exact-fit model (FE-2). Subsequent increases in the interference resulted only small reductions in the relative micromotion. Studies have shown that micromotion below 50µm would permit bone in-growth [7, 8]. All the interference models in the present study showed micromotion values less than 7µm, while the exact-fit models showed micromotion between 60-150µm. Relative displacements as large as these would impede bone ingrowth and increase the risk of long-term implant loosening [13, 14].

Therefore, the results from the present study suggest that the combined effects of the friction and interference-fit at the cup-bone interface greatly enhance the initial stability of the acetabular cup, while improving long-term implant stability as the minimal micromotion would encourage osseointergration. It most also be emphasized that other factors, such as age and disease, which cause a deterioration in bone quality, could also contribute to the effects on the initial and long-term stability of the prosthesis. Here, a lack of mechanical strength and support, would increase the risk of implant loosening and bone fracture.

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REFERENCES