EFFECT OF ACETABULAR CUP ORIENTATION ON THE CONTACT MECHANICS OF METAL-ON-METAL HIP RESURFACING PROSTHESES

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INTRODUCTION

The metal-on-metal hip resurfacing has been extensively used recently, due to the potential advantages of biomechanics and biotribology these devices offer over conventional total hip arthroplasty. However, despite encouraging medium-term clinical reports of these resurfacing arthroplasties, a number of problems have been identified from clinical retrievals, including significant elevation of wear when the implant is mal-positioned [1-4]. It is also known that the wear of these bearings and consequently biological implications critically depend on effective lubrication [5]. Our hypothesis is that implant mal-position can result in edge contact, leading to deteriorations in lubrication and increases in wear. The aim of this study was to investigate the effect of the acetabular cup orientation on the contact mechanics of metal-on-metal hip resurfacing prostheses, in particular to identify the implant positions that can result in edge contact.

METHODOLOGY AND FINITE ELEMENT MODELS

The finite element (FE) method was used. A generic metal-on-metal hip resurfacing prosthesis based on currently available designs was modeled. The bearing diameters of the femoral head and acetabular cup components were 54.49mm and 54.6mm respectively, with a diametral clearance between the head and the cup of 0.11mm. The resurfacing components were implanted into a hemi-pelvic hip joint bone model [6], as shown in Fig. 1. All the materials in the FE model were assumed to be homogenous, isotropic and linear elastic [7]. The FE models consisted of approximately 80,000 elements, which were meshed in I-DEAS (Version 11, EDS, USA) and solved using ABAQUS (Version 6.7-1, Dassault Systèmes). The orientation of the acetabular cup was varied, from inclination angles of 35° to 65°, and anteversion angles from 0° to 30°. Contact at the bearing surfaces between the cup and femoral head was modeled using frictionless surface-based elements, simulating a fully lubricated situation, as coefficients of friction less than 0.1 within a boundary lubrication regime would not have appreciable effects on the predicted contact mechanics. For this study, the femoral component was fixed into the femur (except the guide pin) using PMMA cement (approximately 1mm thick) with an inclination angle of 45° and an anteversion angle of 10°. The other contact interfaces in the FE model were assumed to be rigidly bonded. The hip joint model was loaded through a fixed resultant hip joint contact force of 3200N, and was applied through medial, anterior muscle forces and subtrochanteric forces to simulate the mid-to-terminal stance phase (approximately 30% - 50%) of the gait cycle [8-10].

RESULTS AND DISCUSSION

The effects of the cup implant position on the contact area and contact pressure at the bearing surfaces can be seen in Fig. 2. Edge contact was detected once the inclination angle became greater than 65°. Increasing the anteversion angle resulted in a further shift of the contact area towards the edge of the cup. No edge contact was found for the anteversion angles up to 30° and inclination angles below 55°. Only contact mechanics were directly modeled in this study, which should provide some indirect indications how the lubrication and wear of these devices may perform. Edge loading not only elevates the contact stress at the rim of the cup, it more importantly, can block the lubricant entry into the contact and therefore cause lubricant starvation. It is well known that metal-on-metal bearings critically depend on effective lubrication. Under adverse lubrication conditions, wear of metal-on-metal bearings can be significantly increased. Important parameters which compromise lubrication identified in previous studies include; large clearances [5] and increased swing phase load [11]. The current study further supports the adverse effect of the high cup angles and is consistent with both experimental and clinical studies reported recently. Although not modeled in this study, edge loading may be avoided by increasing the cup coverage and using lower cup angles. However, such approaches may compromise the range of motion. Optimisation in terms of both tribology of the bearing surfaces and biomechanics is required for metal-on-metal hip resurfacing prostheses. This study highlights the importance of surgical techniques on the contact mechanics and tribology of metal-on-metal hip resurfacing and potential outcome of these devices.

REFERENCES