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Influence of interface condition and implant design on bone remodelling and failure risk for the resurfaced femoral head

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ABSTRACT

Resurfacing of the femur has experienced a revival, particularly in younger and more active patients. The implant is generally cemented onto the reamed trabecular bone and theoretical remodelling for this configuration, as well as uncemented variations, has been studied with relation to component positioning for the most common designs. The purpose of this study was to investigate the influence of different interface conditions, for alternative interior implant geometries, on bone strains in comparison to the native femur, and its consequent remodelling. A cylindrical interior geometry, two conical geometries and a spherical cortex-preserving design were compared with a standard implant (ASR, DePuy International, Ltd., UK), which has a 3° cone. Cemented as well as uncemented line to line and press-fit conditions were modelled for each geometry. A patient-specific finite element model of the proximal femur was used with simulated walking loads. Strain energy density was compared between the reference and resurfaced femur, and input into a remodelling algorithm to predict density changes post-operatively. The common cemented designs (cylindrical, slightly conical) had strain shielding in the superior femoral head (>35% reduction) as well as strain concentrations (strain>5%) in the neck regions near the implant rim. The cortex-preserving (spherical) and strongly conical designs showed less strain shielding. In contrast to the cemented implants, line to line implants showed a density decrease at the centre of the femoral head, while all press-fit versions showed a density increase (>100%) relative to the native femur, which suggests that uncemented press-fit implants could limit bone resorption.

1. Introduction

Resurfacing procedures have demonstrated slightly higher failure rates to conventional stems in national registers (de Steiger et al., 2010; Prosser et al., 2010). However, their predominant failure mode of neck fracture (Morlock et al., 2006; Zustin et al., 2010) indicates opportunities for mechanical improvement. Neck fracture occurs predominantly in the first few months post-operatively and is a multi-factorial problem. Some of the identified patient risk factors are the femur size and bone quality. On the surgical site excessive cement mantle thickness, vascular damage, notching of the neck or component mal positioning during implantation are known to increase fracture risk (Siebel et al., 2006; Mont et al., 2007; Mont and Schmalzried, 2008; Amstutz and Le Duff, 2009; Morlock et al., 2008). This can be minimised by careful surgical technique. However, the implant itself modifies the loading of the bone, which might lead to direct overload or adverse remodelling (Siebel et al., 2006). Finite element models have shown the highest peak strains directly post-operatively to occur at the superior femoral neck, below the prosthesis rim (Gupta et al., 2006; Watanabe et al., 2000). Stress shielding has also been suggested beneath the implant in the superior femoral head, which could lead to bone loss (Gupta et al., 2006; Pal et al., 2009a, 2009b). Most femoral resurfacing procedures are cemented. A numerical study (Ong et al. 2006) suggested slightly less bone resorption in the superior head for an uncemented Birmingham-Hip (BHR) component, which is normally cemented. The interface condition in the current study was therefore varied to represent cemented and uncemented line to line as well as press-fit designs.

The aim of this study was to identify preferable interface conditions and implant designs to overcome the problems of stress-shielding and high fracture risk that are associated with femoral resurfacing implants.

2. Methods and material

2.1. Implant designs

Strain distributions for varying bonding conditions and implant designs were compared with those acting in the native femur both directly post-operatively and

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