Short stems are less likely to lead to bone resorption; bone remodelling following THR.

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INTRODUCTION

Bone resorption around hip stems, in particular periprosthetic bone loss, is a common observation post-operatively. A number of factors influence the amount of bone loss over time and the mechanical environment following total hip replacement is important; conventional long stem prostheses have been shown to transfer loads distally, resulting in bone loss of the proximal femur (Figure 1a). More conservative, short stems have been recently introduced to attempt to better replicate the physiological load distribution in the femur. In addition, the short stem offers a bone conserving alternative to the long stem (20% less bone displaced for a correctly implanted MiniHip relative to the corresponding Metafix) as a lack of viable bone stock may compromise the longevity of the revision prosthesis (Figure 1b). The aim of this study was to evaluate the bone mineral density (BMD) change over time, in a femur implanted with a short or long stem. Results were presented in terms of Gruen zones (Gz1 - 7), a clinically recognised system for defining regions of the proximal femur based on implant geometry.

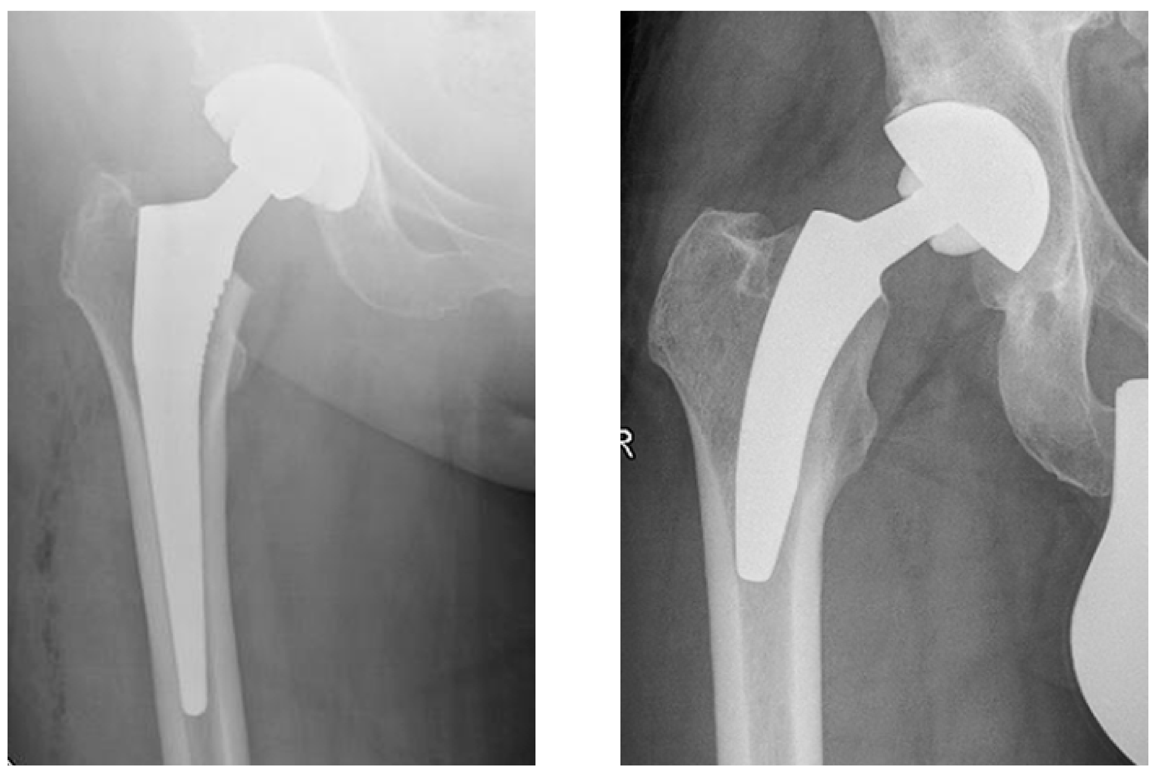

Figure 1: a) Conventional long stem prosthesis b) MiniHip short stem prosthesis

METHODS

Finite element (FE) models of two implanted femurs, one implanted with a short (Minihip, Corin, UK) and the other, with a long (Metafix, Corin, UK) hip stem were used to simulate bone remodelling under a physiological load condition (stair climbing). Results were presented relative to an FE model of an unimplanted femur (Figure 2 a-d).

The magnitudes and directions of the muscle forces and joint reaction force were obtained from Heller et al[1,2]. A strain-adaptive remodelling theory[3] was utilised to simulate remodelling in the bone after virtual implantation. COMSOL Multiphysics software was used for the analysis. The strain component of the remodelling stimulus was strain energy density per unit mass, calculated in the continuum model from strain energy density and apparent density.

Bone mass was adapted using a site-specific approach in an attempt to return the local remodelling stimulus to the equilibrium stimulus level (calculated from the unimplanted femur). The minimal inhibitory signal proposed by Frost[4], was included in the model and described by a 'lazy zone', where no bone remodelling occurred.

The three dimensional geometry of the femur was constructed from computed tomography (CT) data of the donor (female, 44 y/o, right side). Elemental bone properties were assigned from the Hounsfield Unit values of the CT scans. The elastic modulus (E) of the bone was assumed to be isotropic and was determined using a relationship to the apparent bone density[4,5]. The Poisson's ratio for the bone regions varied between 0.2 and 0.32 depending on the apparent density of the bone[6].

The period of implantation analysed was two years. The muscle forces and joint contact loads applied were ramped linearly from zero to full load over a period of two weeks, representing the estimated post operative rest period of a patient.

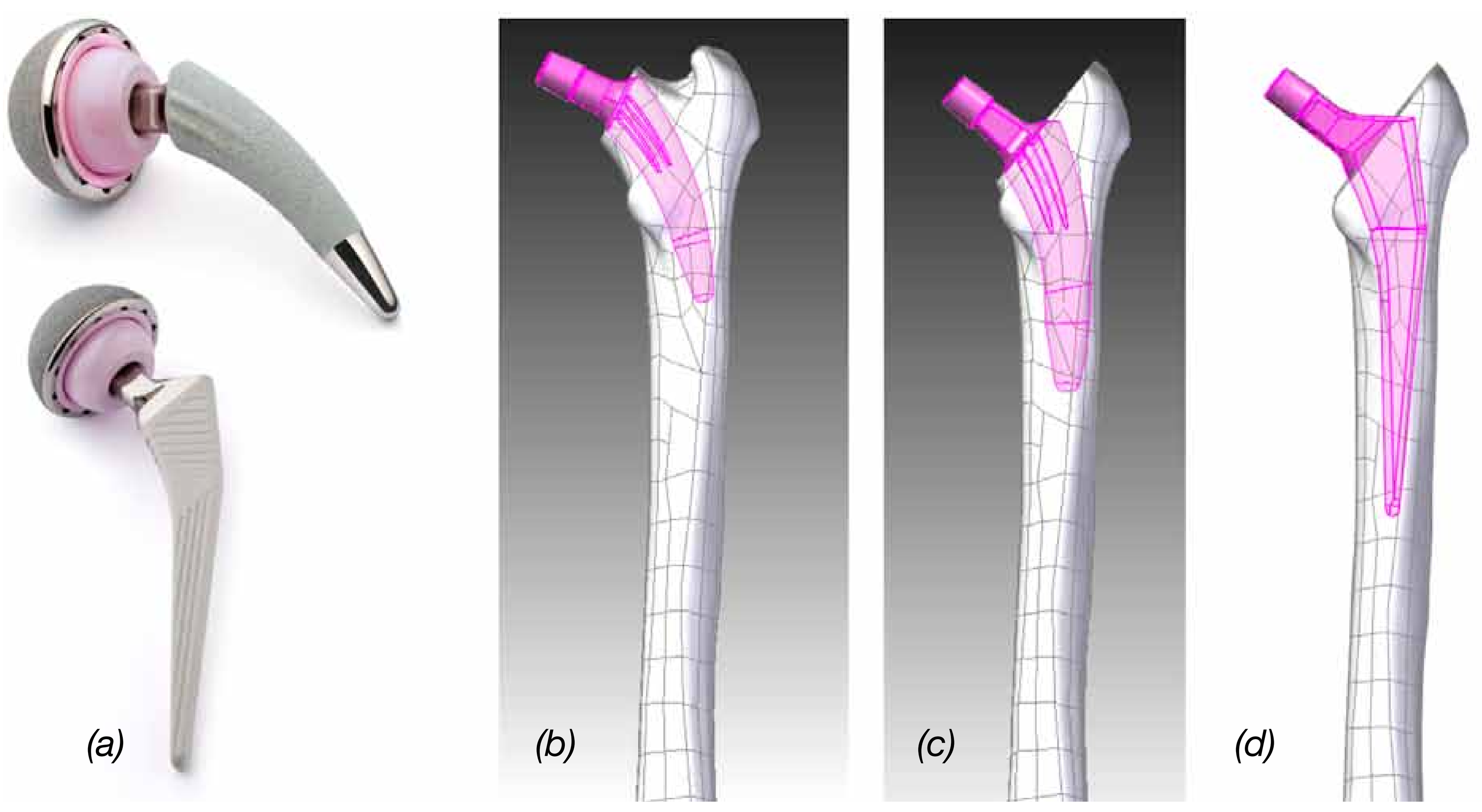

Figure 2: a) MiniHip and MetaFix stems b) size 2 MiniHip implanted c) size 5 MiniHip implanted d) size 2 MetaFix implanted

RESULTS

The overall percentage BMD change observed for Gruen zones 1 through to 7, were -14%, +11%, +23%, +3%, +11%, +4%, and -1% respectively at two years for the MiniHip. The corresponding overall percentage BMD change observed for Gruen zones 1 through to 7 for the MetaFix were -1%, +3%, +7%, +3%, +2%, +1% and -18% respectively (Figure 3,4).

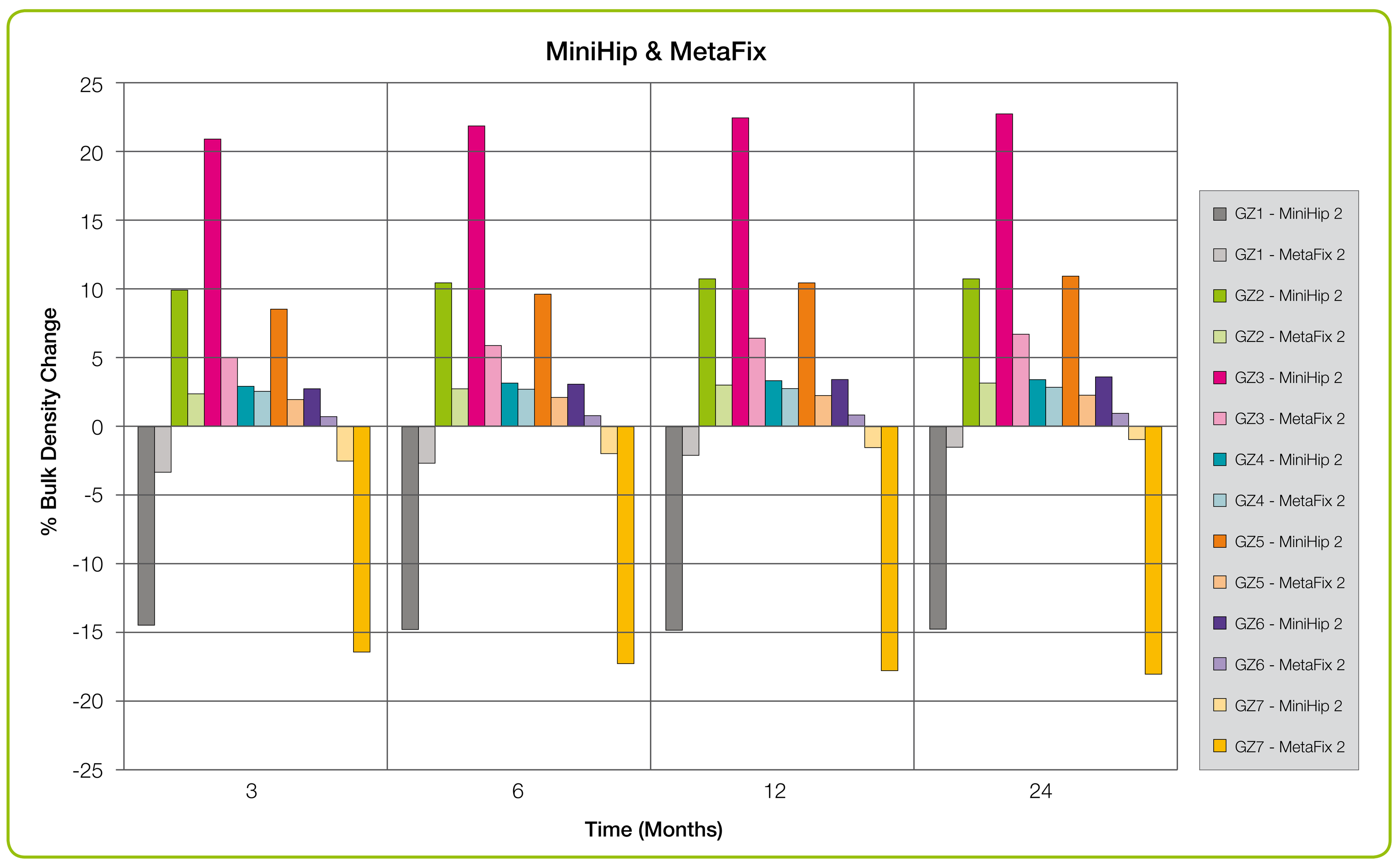

Figure 3: BMD change for the two stems

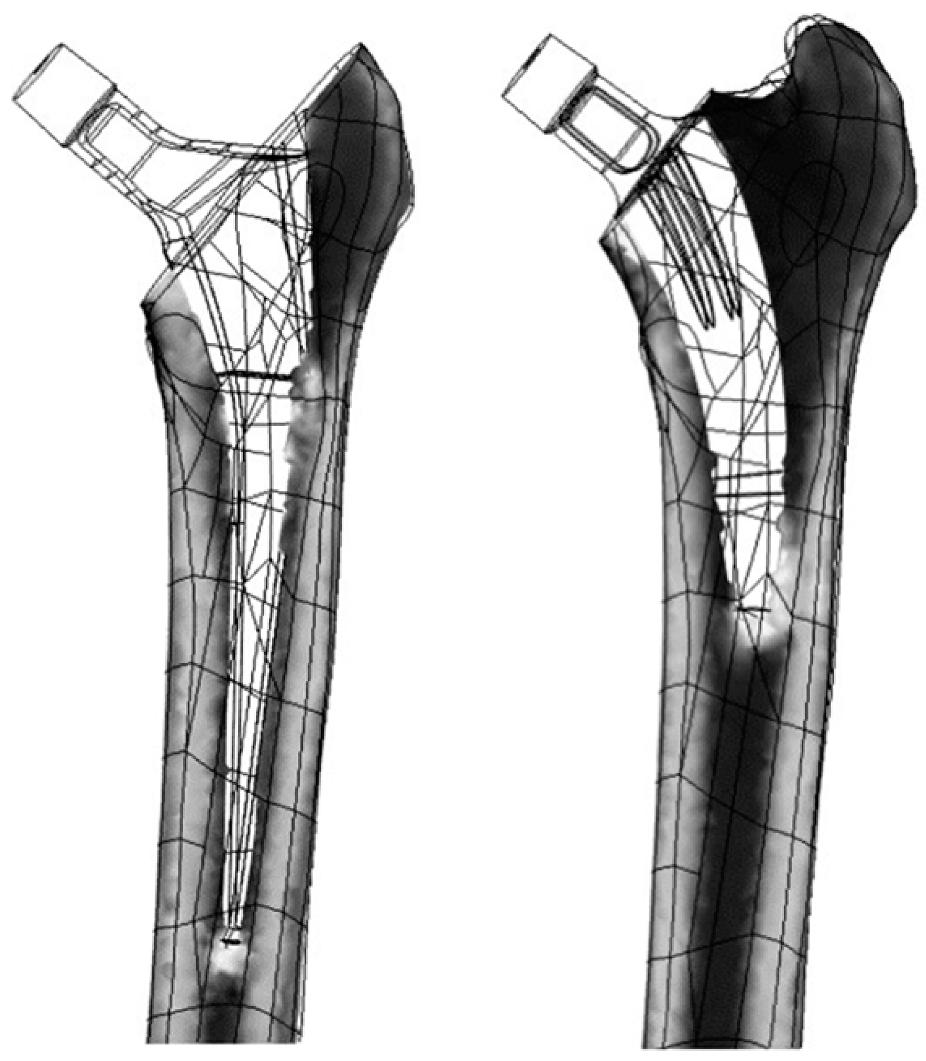

Figure 4: Virtual DEXA images showing bone resorption for the long and short stem

DISCUSSION

Considerably more bone resorption occurs in Gruen zone 7 with the MetaFix long stem relative to the MiniHip short stem. Short stem implants have the potential to be more bone conserving compared to conventional stems, and to minimise periprosthetic bone loss when correctly sized and implanted.

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