Bone Remodelling Following total Hip Replacement: Short vs. Long Stem Implants

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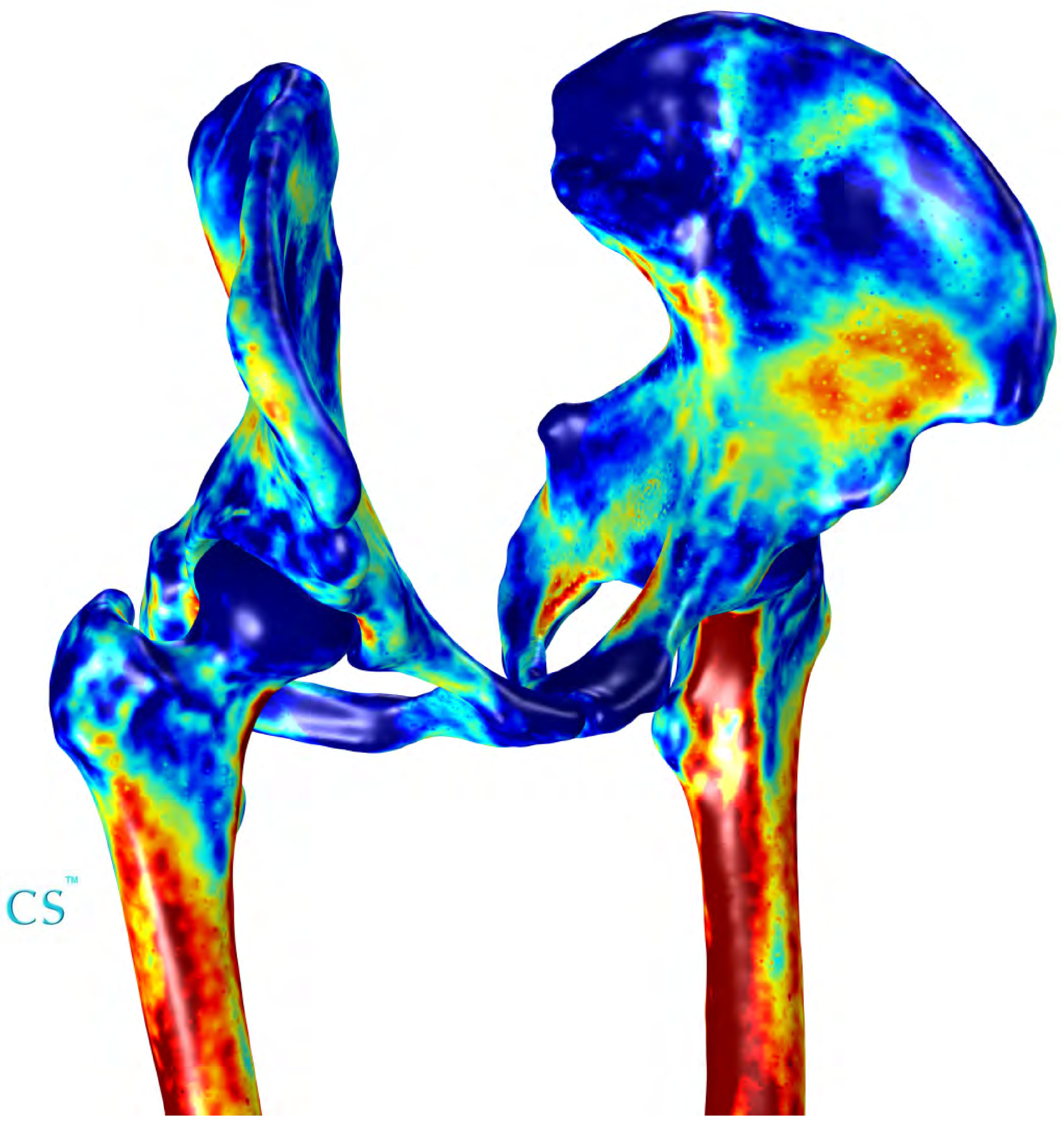


INTRODUCTION

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 & the mechanical environment following total hip replacement (THR) is important. Conventional long stem prostheses have been shown to transfer loads distally, resulting in bone loss of the proximal femur. More conservative, short stems have recently been introduced to attempt to better replicate the physiological load distribution in the femur.

AIM

The aim of this study was to evaluate bone mineral density (BMD) change over time, in a femur implanted with either a short or a long stem.

Equations 1. Bone Material Properties as Function of Hounsfield Units (HU)

$$\rho_{app} = f(HU)$$

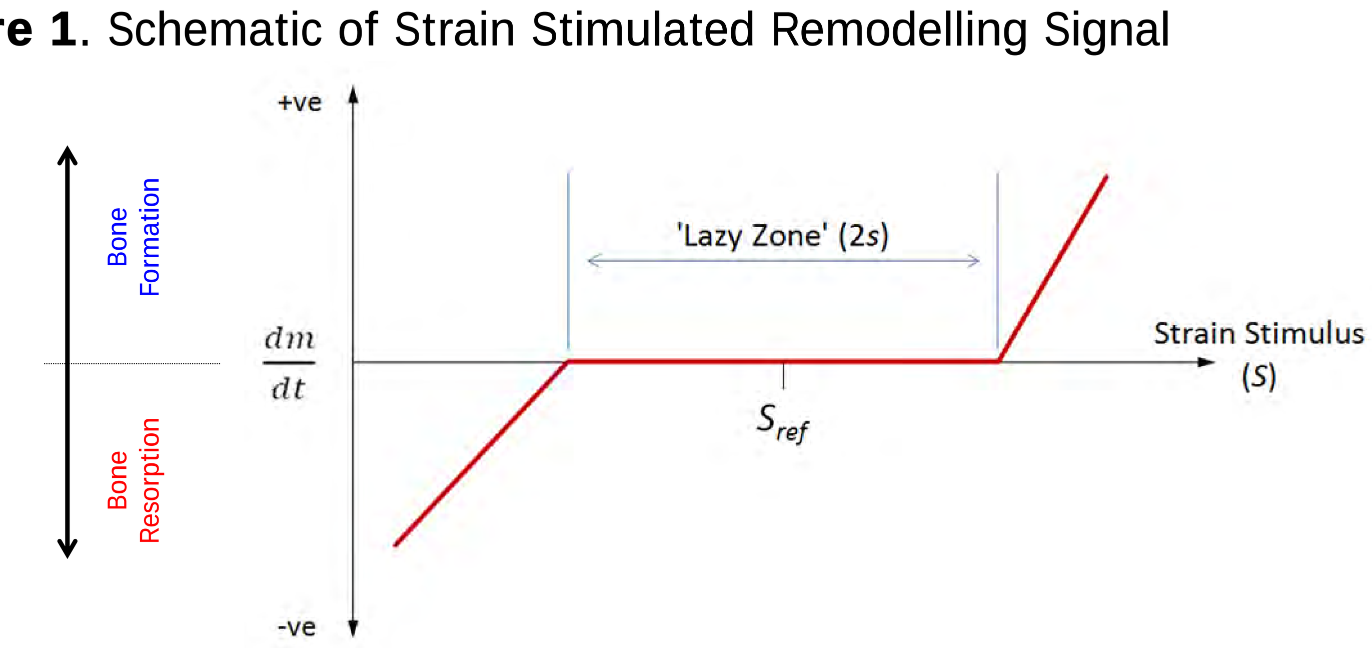
$$E = 6.4\rho_{app}^{\ 1.54}$$

$$\upsilon = \begin{bmatrix} 0.2 & \text{if} & \rho < 1000 \\ \frac{0.12}{500}\rho_{app} - 0.04 & \text{if } 1000 \le \rho \le 1500 \\ 0.32 & \text{if} & \rho > 1500 \end{bmatrix}$$

Table 1. Patient Specific Bone Properties vs. Validated Femur

	Minimum (MPa)	Mean (MPa)	Maximum (MPa)
Femur Modulus	0.1	8.3	23.3
Validated Femur Modulus	0.5	6.6	22.5

Figure 1. Schematic of Strain Stimulated Remodelling Signal



METHOD

COMSOL was used to simulate bone remodelling under a physiological load condition (20% gait cycle), when a short (Minihip, Corin, UK) and a long (Metafix, Corin, UK) hip stem were implanted in a patient specific femur. The patient specific femur was constructed using CT data. Bone material properties were calculated using relationships from literature [2-4]. The magnitudes and directions of the muscle forces and joint reaction force were obtained from literature [1]. A strain-adaptive remodelling theory was utilised to simulate remodelling [2] in the bone after virtual implantation, where the strain energy density per unit mass of the implanted models were compared to that of an intact (un-implanted) femur model. A minimal inhibitory signal [3], was implemented in the bone remodelling algorithm & described by a 'lazy zone', where no bone remodelling occurred (Figure 1).

RESULTS

Good correlations (Table 1) between the patient specific bone material properties & that of a validated femur [6] were obtained. Short stems transfer load to the proximal femur, with ~25% more cortical strain on the medial side, compared to that of the long stem. However, if an oversized short stem is implanted, the resultant medial strain was similar to that of the long stem. Assessment of implant Gruen Zones, the observed SED for Gruen Zone 7 was very similar for the Short Stem & Intact model, while a 20% difference was observed between the long stem & intact model (Figure 2). Comparing the short & long stem, there is 45% BMD loss in long stem compared to 12% in short stem. While the correctly sized Minihip resulted in ~20% less bone resection. Percentage BMD change over time for the two implants (Figure 3), showed bone loss in Gruen Zones 1,2, 6 & 7 for both short & long stems. The long stem showed a ~43% loss in Gruen Zone 7 compared to a ~15% in the short stem over 2 years.

Figure 2. Short & Long Stem Model Percentage Change in SED vs. Intact Model for Various Gruen Zones

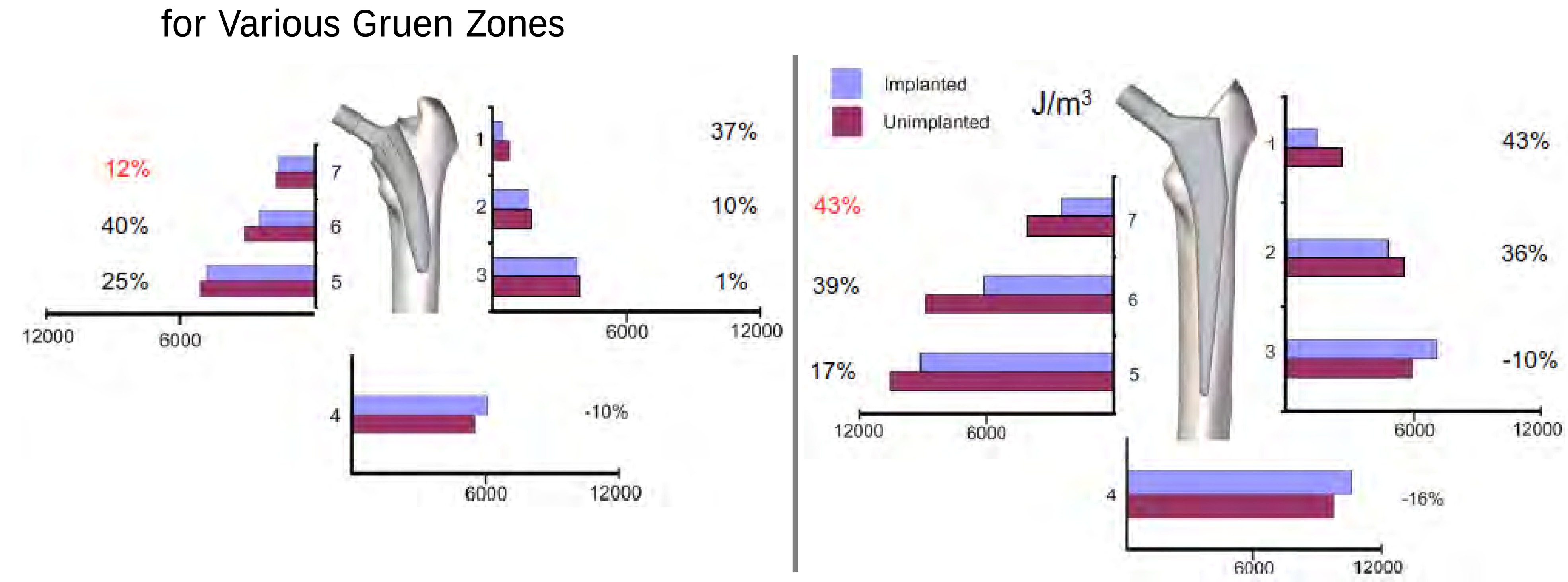
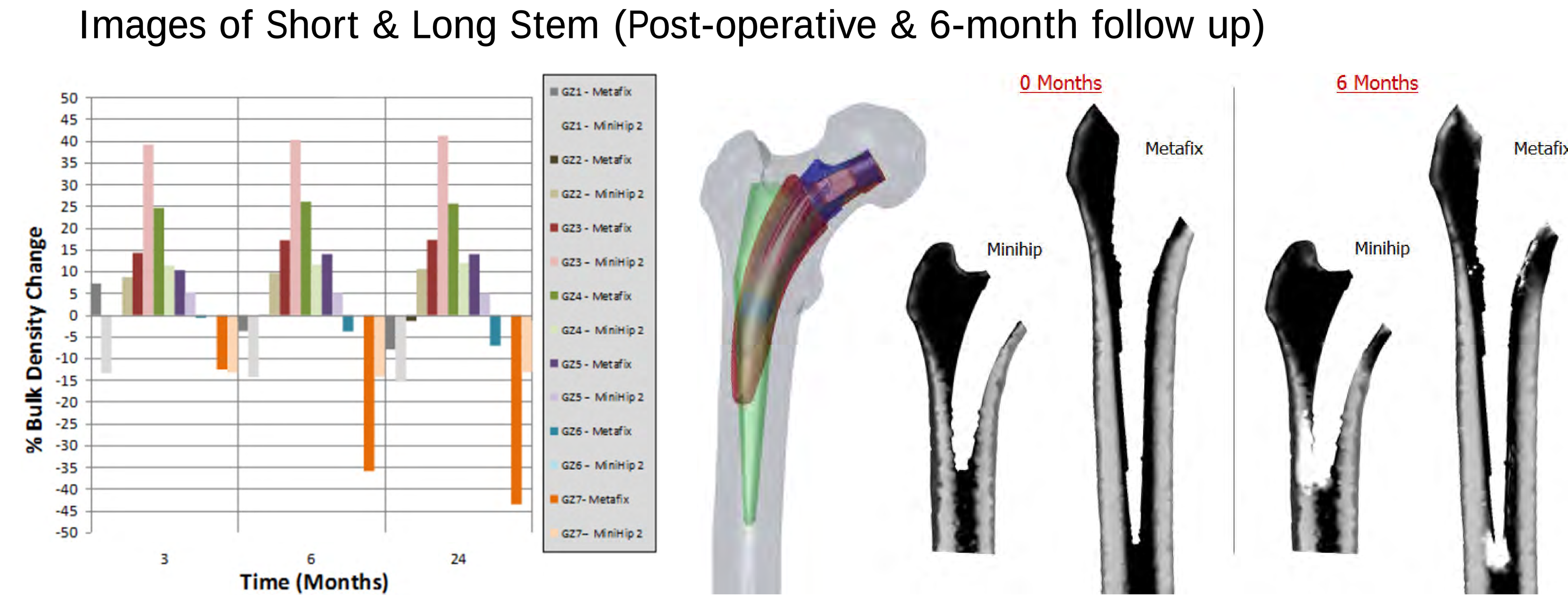


Figure 3. a) Change in Gruen Zone BMD Percentage vs. Time & b) Virtual DEXA Images of Short & Long Stem (Post-operative & 6-month follow up)



DISCUSSION & CONCLUSION

The overall bone remodelling response after 2 years of implantation showed long stem designs disrupt the mechanical environment more than short stems, which lead to greater bone loss over time. High SED & contact pressure at the tip of the short stem may lead to pedestal/bone in-growth & possible thigh pain.

Short stems have the potential to minimise periprosthetic bone loss & are bone conserving & provide clinicians with greater flexibility with revision surgery.

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