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Bone Remodelling Study of Metal and all-Ceramic Acetabular Resurfacing Cups

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INTRODUCTION: Hip resurfacing offers a more bone conserving solution than total hip replacement (THR) but currently has limited clinical indications related to some poor design concepts and metal ion related issues. Other materials are currently being investigated based on their successful clinical history in THR such as Zirconia Toughened Alumina (ZTA, BIOLOX *delta*, CeramTec, Germany) which has shown low wear rates and good biocompatibility but has previously only been used as a bearing surface in THR. A newly developed direct cementless fixation all-ceramic (ZTA) resurfacing cup offers a new solution for resurfacing however ZTA has a Young's modulus approximately 1.6 times greater than CoCr – such may affect the acetabular bone remodelling.. This modelling study investigates whether increased stress shielding may occur when compared to a CoCr resurfacing implant with successful known clinical survivorship.

METHODS: A finite element model of a hemipelvis constructed from CT scans was used and virtually reamed to a diameter of 58mm. Simulations were conducted and comparisons made of the 'intact' acetabulum and 'as implanted' with monobloc cups made from CoCr (Adept®, MatOrtho Ltd, UK) and ZTA (ReCerf ™, MatOrtho Ltd. UK) orientated at 35° inclination and 20° anteversion. The cups were loaded with 3.97kN representing a walking load of 280% for an upper bound height patient with a BMI of 35. The cup-bone interface was assigned a coulomb slip-stick function with a coefficient of friction of 0.5. The percentage change in strain energy density between the intact and implanted states was used to indicate hypertrophy (increase in density) or stress shielding (decrease in density).

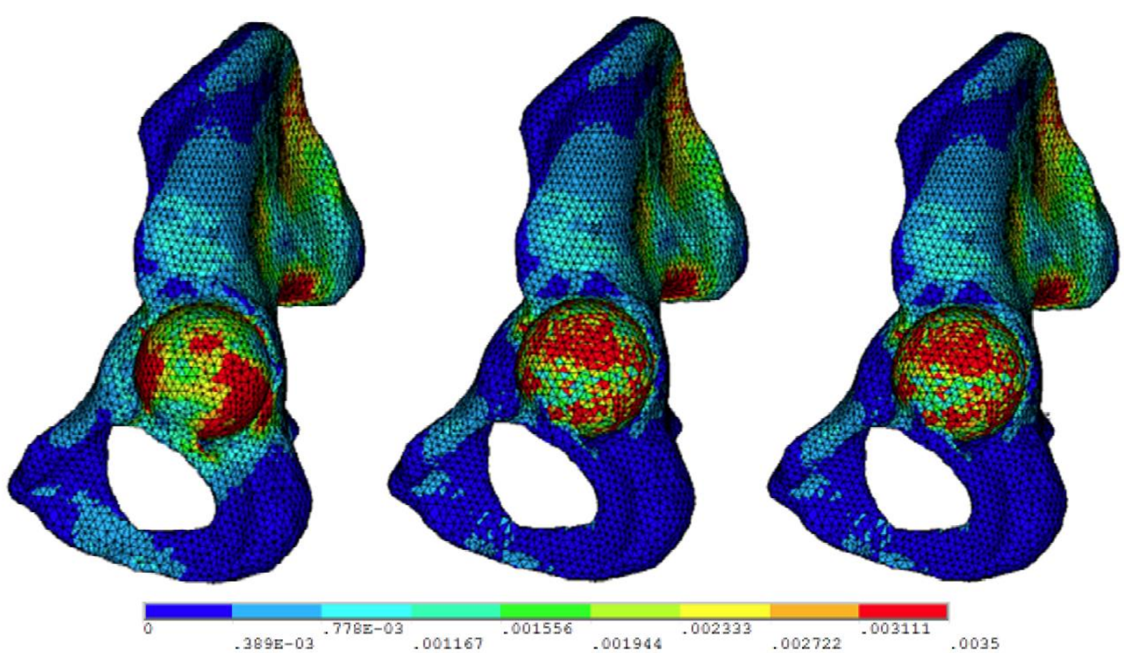

Figure 1: Predicted strain for intact (left) and implanted models to metal cup (centre) and ceramic cup (right) under upper bound walking loading.

RESULTS: Implanting both cups changed the strain distribution observed in the hemipelvis, Figure 1. The change in strain distribution was similar between materials and indicated a similar response from the bone, Figure 2. In both implanted cases, the inferior peri-acetabular bone around the implant indicated a reduction in bone strain. The bone remodelling distribution charts show that regardless of threshold remodelling stimulus level (75% in elderly, 50% in younger patients) the CoCr and ZTA cups were expected to produce the same bone response with only a small percentage of the bone in the hemipelvis indicating stress shielding or hypertrophy, Figure 3.

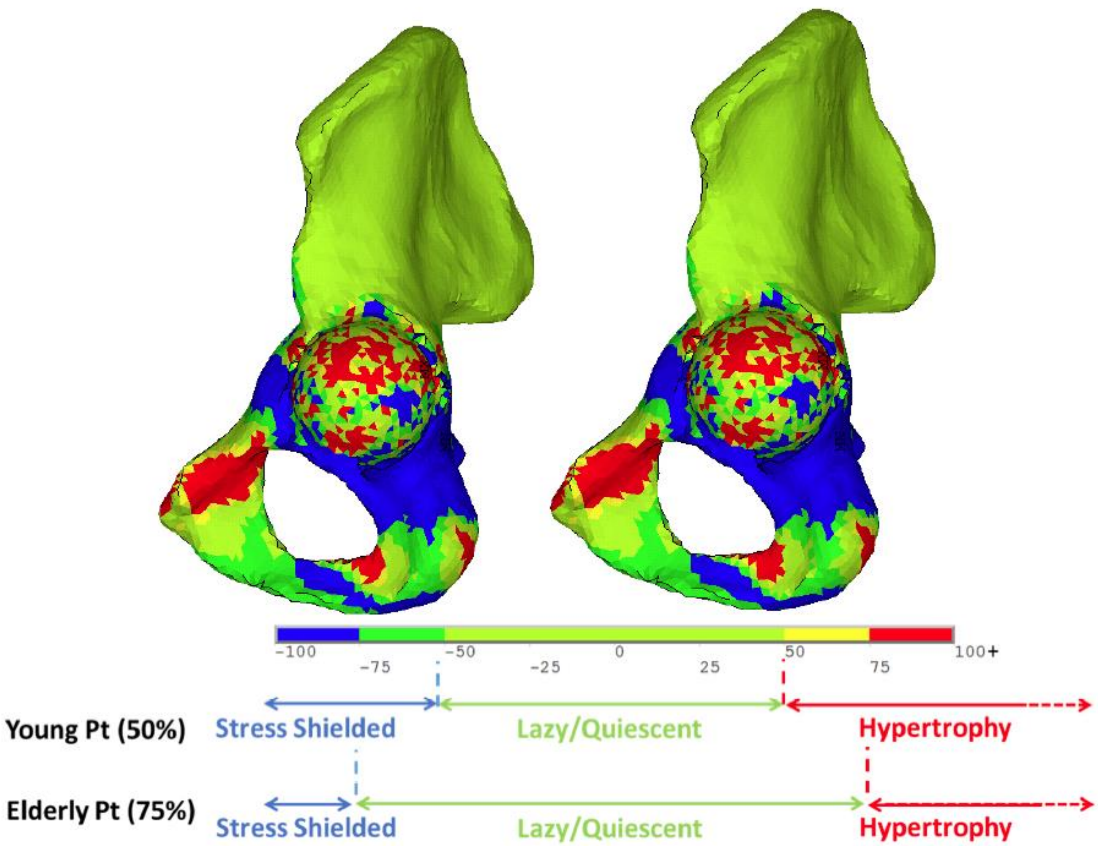

Figure 2: Percentage change in strain energy density per unit of bone mass in implanted bone compared to intact bone for metal (left) and ceramic (right) acetabular implants.

DISCUSSION: Currently only metal cups are used for cementless fixation but improvements in design and technology have made it possible to engineer a thin-walled, direct fixation, all-ceramic cup. Both CoCr and ZTA are an order of magnitude greater than the Young's modulus of cortical bone altering the bone strain but changing the material from CoCr to a stiffer ZTA did not change the expected bone remodelling response. Given the clinical history of metal cups without loosening due to bone remodelling, the study indicates that a ZTA cup should not lead to increased stress shielding and is potentially suitable for as a cementless cup for both resurfacing and THR.

SIGNIFICANCE: An all-ceramic cup is unlikely to lead to increased stress shielding around the acetabulum due to the change in material.

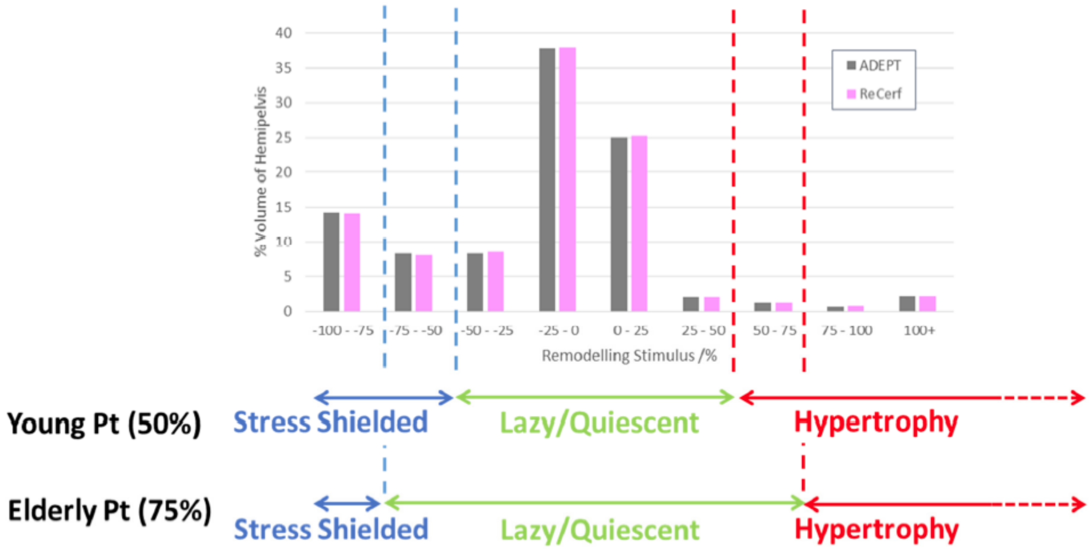

Figure 3: Histogram of bone remodelling stimulus over percentage bone volume for metal cup (Adept, grey) and a ceramic cup (ReCerf, pink)