ABSTRACT INTRODUCTION:

Aseptic loosening still remains a long term problem in cemented total hip arthroplasties. Mechanical failure of the cement mantle is thought to initiate at pores within the cement body that act as stress risers. The porosity within a cement mantle is directly affected by temperature, a variable that appears to have no adverse changes in any of the mechanical properties of the material (Parks et al, 1998). Femoral component heating was first proposed as a method to reduce the curing time of bone cement (Dall et al,1986). This practice has since been found to reduce the porosity at the stem-cement interface by reversing the direction of polymerisation (Jafri et al, 2004). From computer analysis of the transient heat transfer it has been suggested that 44°C is the minimum temperature required to initiate polymerisation of the cement at the bone-cement interface (Bishop et al, 1996).

The object of this study was to investigate the changes in porosity distribution within two different bone cements with extreme mantle thicknesses, as a function of femoral stem temperatures.

METHODS:

The model femora used for this study were maintained at a constant temperature of 37°C while the stem temperature varied between 21°C, 37°C and 44°C. The femora were formed from dental plaster as it has a similar thermal conductivity to bone. Mould sizes were created to generate cement mantles of 2mm and 10mm thickness laterally around an Exeter stem (Stryker, USA). Palacos R (BioMet Merck, UK) and Simplex P (Stryker, USA) were used in this study, each cement was mixed under vacuum for 2 minutes, introduced into the mould in a retrograde fashion after 3 minutes and the stem inserted after 4 minutes, both from the start of mixing, at a constant rate of 300mm/min. An insertion test fixture was used to generate the mould cavity and for centrally positioning the prosthesis into the cement filled cavity. The mould and the pre-heated stems were kept in an incubator and removed just prior to insertion. For the two cement types, 6 mantles were generated for each test group.

A 10mm deep mantle ring was removed from the middle section of the bone cement mantle with minimal material disruption. The cement ring was then mounted in an epoxy resin and polished. Each prepared surface section was then examined under a Zeiss microscope at 5x magnification and a set of digital images across the lateral ends taken using a camera (Sony 3CCD) mounted on the microscope. The number of required images varied with the mantle thickness. The images were then analysed using a custom developed algorithm (Matlab with Image Analysis Toolbox, Mathwork, USA). From this, the percentage porosity of each of the sections was recorded, along with the number of pores/mm. The stem/cement and bone/cement interfaces considered within this study include the cement up to 1mm depth from the transverse interface. Beyond this the sections were considered in 2mm depths. Statistical analysis was undertaken using a one way ANOVA and an LSD post Hoc test using SPSS (SPSS Inc, USA) statistical package, significance was assumed for p<0.05.

RESULTS:

The percentage porosity measured in Palacos R was significantly greater than that recorded for Simplex under all test conditions (p<0.04).

2mm cement mantle: At 21°C, Palacos R had the highest porosity at the stem-cement interface (7.7±3.3%). At 37°C the bone-cement interface had the higher porosity. At 44°C, the total porosity had significantly reduced to 1.9±2.5% (p=0.027) and there was no apparent difference between the two interfaces. At 21°C and 37°C the porosity at the stem-cement interface was significantly higher than the porosity at the 44°C stem interfaces (p=0.017 and p=0.027, respectively). Simplex P indicated similar trends to the Palacos R except the drop in porosity at 44°C from the 37°C or 21°C stem was not statistically significant in this case (Figure 1). The number of pores/mm gave an indication of the type of porosity: Palacos R mantles displayed a large volume of micro-porosity, while the Simplex P mantle porosity was mainly due to a small number of macro-pores (Figure 2).

10mm cement mantle: The regional porosity within the cement was reduced across the mantles for both cement types. At 21°C Palacos R had the highest porosity at the stem-cement interface (1.4±0.7%), gradually reducing across the cement mantle. With the 37°C and 44°C stems this trend was reversed. At the stem-cement interface itself, the lowest porosity was recorded with the 44°C stem (1.0±0.4%), where the porosity of the cement at the bone-cement interface was significantly greater than the porosity across the entire mantle at 21°C (2.8±2.9%) (p<0.04). The trend in the larger mantles suggested that as the stem temperature was increased the region of greatest porosity moved from the stem-cement interface towards the bone-cement interface. With Simplex P, there was a similar decrease in the porosity at the stem-cement interface as the stem temperature increased. However the porosity appeared to be greatest towards the middle of the mantle for all the stem temperatures (Figure 3).

DISCUSSION:

The results confirm that the porosity at the stem-cement interface decreases as the stem temperature increases and appears to ‘transport’ the porosity towards the cooler bone-cement interface. The 2mm mantles indicate that the porosity is reduced at this interface, however it is not clear how the porosity is then distributed. With the 10mm mantles, the Palacos R porosity gradually increases across the cement depth, culminating in the maximum porosity occurring at the bone-cement interface. The Simplex P porosity increases across the cement mantle, but the maximum porosity is identified within the mid section of the cement. Increasing the stem temperature thus appears to redistribute the bone cement porosity away from the stem-cement interface.

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REFERENCES:


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