DO FEMORAL CEMENT MANTLE THICKNESS AND CENTRALISATION AFFECT CEMENT CRACKING IN TOTAL HIP REPLACEMENT?

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INTRODUCTION

The cement mantle is an important contributory factor in the failure of cemented total hip replacements. Failure of fixation is associated with cement fractures. Although there is broad consensus as to the acceptable range of cement mantle thickness, surgical practice is not consistent. Surgeons in Europe generally prefer a thinner cement mantle than those in the US. This is exemplified by the Stanmore Hip, US surgeons using a larger rasp to prepare the femoral canal for a given femoral stem size compared with surgeons in Europe. The use of distal centralisers may also affect cement mantle thickness.

The aim of this study was to investigate the effect of cement mantle thickness on cracking of the cement mantle, where cement thickness was varied using different rasp sizes and poor centralisation.

A previous finite element study1 indicated that peak cement stresses would be lower in a thicker cement mantle. We hypothesised that thicker cement would lead to reduced numbers and lengths of cracks, and that a larger rasp would lead to a thicker cement mantle and hence to reduced numbers and lengths of cracks. Due to the increased stress concentration seen around the tips of poorly centralised prostheses, we also predicted that poor centralisation would lead to increased crack lengths and numbers.

MATERIALS & METHODS

Thirteen synthetic femurs (Sawbones, Pacific Research Laboratories, Inc.) were prepared using the standard surgical procedure for the Stanmore Hip. Either the larger US rasps or the UK rasps were used. Identical standard size-2 Stanmore femoral components were inserted in all cases, using vacuum-mixed Palacos-R bone cement with a retrograde fill. Centralisation was ensured using a custom insertion rig for good alignment and a distal centraliser, and poor centralisation achieved by deliberate valgus orientation of the stem with no centraliser. Appropriate uniformity of the cement mantle and degree of centralisation were then confirmed using anterior-posterior and lateral radiographs.

These methods were used to generate three test groups: (1) those produced using the US rasp, with good centralisation (n=5); (2) those produced using the UK rasp, with good centralisation (n=5); and (3) those produced using the UK rasp, with deliberate valgus positioning (n=3).

All implanted femurs were then fixed distally and subjected to a simulated stair-climbing load using a hydraulic loading machine. Femurs were oriented at 15° of adduction and flexion relative to a vertical hip joint force2. A sinusoidal load of 0.4-4.0 kN at 3.0 Hz was applied for 4 million cycles.

After loading, the femurs were sectioned at 5 mm intervals, using a water-cooled, diamond-coated saw to minimise surface damage. The sections were then stained with dye penetrant to facilitate crack identification and measurement (see Fig.1).

Under 10x magnification, image analysis software was used to measure cement thickness and crack lengths. Cement thickness was measured radially at eight 45° intervals per section, as shown in Fig.2. Cracks were measured and their locations categorised into the same 45° sectors.

Mann-Whitney U-tests were used for all statistical analysis.

RESULTS

The well centralised US and UK groups had significantly different cement thicknesses (p<0.05) and the minimum thicknesses recorded per section were significantly different between all three groups (p<0.05).

No significant difference was found between groups for either the number of cracks per femur or the lengths of cracks. However, the ratio of crack length to local cement thickness was found to be significantly different for the US and UK groups (p<0.005, see Graph 1). Cracks occurring in cement less than 0.9 mm thick were significantly longer than those occurring in thicker cement (p<0.001). Regions of less than 0.9 mm comprised only 9% of all thickness measurements, but contained 18% of all cracks. Cracks occurring in the cement mantle around the distal 4 cm of the implant were significantly longer in the poorly centralised group than in the well-centralised group (p<0.05, see Graph 2).

DISCUSSION

Our results suggest that crack growth is independent of rasp size, and that thinner mantles would therefore fail earlier than thicker mantles, as cracks would need to propagate less far in thin cement before reaching bone, in agreement with previous findings3. Furthermore, regardless of rasp size, the thinnest cement regions were associated with significantly longer and disproportionately more cracks. This suggests that uniformity of cement thickness is more important than rasp size. Deficiencies due to poor centralisation led to longer cracks, which also highlights the importance of effective centralisation.

REFERENCES


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