NUMERICAL ANALYSIS OF A FEMUR RESURFACING CUP

[1]James Cubillo, [1, 2]Chang Jiang Wang
[1]School of Engineering, University of Wolverhampton, UK, TF2 8SD; email: J.P.Cubillo@wlv.ac.uk, Web: www.wlv.ac.uk
[2]Riatec, University of Wolverhampton, UK, WV1 1SB; email: C.J.Wang@wlv.ac.uk, web: www.riatec.org

INTRODUCTION

Wagner [1] developed a method of hip joint arthroplasty by surface replacement. The first clinical trial was in 1976; since then research in this area has continued, and operative techniques and implantation systems have been refined. Hip joint resurfacing offers several advantages over other techniques, most importantly the fact that the femoral neck is left intact.

However, the effects of various designs of femoral resurfacing cup have not yet been fully understood. In this paper, the femoral resurfacing cup was modelled and investigated. Different bone cement materials and various designs of resurfacing femur cup were numerically simulated.

METHODS

A 3D finite element model consisting of a resurfacing cup, bone cement and proximal femur was created using the ANSYS finite element package. The coronal section of the model is shown in Figure 1.

Two types of cancellous bone were considered within the proximal femur. The cancellous bone within the femur head has a Young's modulus of 1300 MPa, and the cancellous bone within the femur trochanteric region has a Young's modulus of 320 MPa [2]; the cortical bone around the trochanter has a Young's modulus of 17000 MPa. The cup is made of Cobalt Chromium, the Young's modulus of which is 210000 MPa and Poisson's ratio 0.3. Two types of bone cement were analysed in this paper with a Young's modulus of 2200 MPa [3] and 2800 MPa respectively.

In this research, we were interested in the region of femoral head and femoral resurfacing cup; only the hip reaction force was applied. In a one-leg stance, a 3 kN load was applied to the femoral head [2]. Ascending and descending stairs and rising from a chair are all activities that increase the posterior component of the joint reaction force and generate large torque, and the anterior-posterior component of force in the joint reaction is up to 45% of the resultant force [4]. The applied forces were distributed over the assumed load-bearing area on the femur head.

For comparative analysis, the following parameters were considered and compared; stress in the cement layer, stress in the bone around the metal stem, and load sharing between the stem and the bone of the femoral neck.

The factors related to the cup design were investigated and discussed. Firstly, the effect of femoral stem bonded or contacted with surrounding bone was investigated. Secondly,

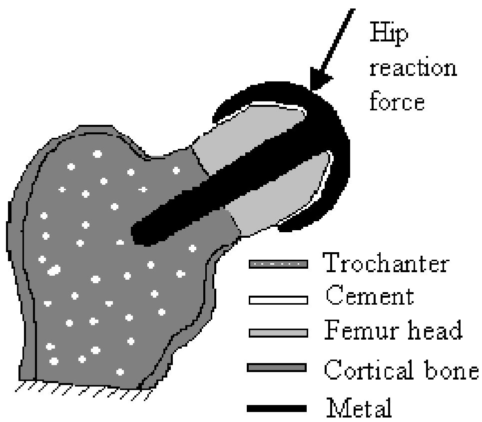

Figure 1: Coronal section of the model and material

the role of the stem in the femoral cup was studied. Finally, the effects of cement thickness, cement material properties, femoral cup depth, stem diameter, and osteoporosis were all investigated.

RESULTS AND DISCUSSION

A femoral cup with a stem reduced the stress in the cement greatly in comparison to a cup without a stem. If a stem was used, the shorter the stem the higher the stress in the cement and femur head bone. When the diameter of stem was decreased, the stress in the cement and femur head bone increased. When the resurfacing cup's depth was reduced, the stress in the cement and femur head bone decreased slightly. Changes in the thickness of the cement layer from 0.5 to 1 and 2 mm did not make much difference to the stresses in the cement and bone. Different material properties of the cement did not change the load sharing between the stem and bone. The more osteoporosis developed in the bone, (i.e. the lower the Young's modulus of the bone), the higher the stress resulted in the cement. All the results showed that the femoral bone carries most of the forces and the stem bears only one quarter to one third of the applied forces in the direction of the stem axis. If the stem were simulated bonded with the bone rather than just in contact with the bone, the stress in the cement was reduced. However, this case may result in stress shielding around the femoral neck with subsequent bone thinning problems.

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