Will the Clinical Outcome of Cemented Modular Neck Total Hip Prostheses be Comparable to Conventional Devices?

INTRODUCTION:

Modular neck total hip arthroplasty (THA) devices afford the surgeon increased intra-operative flexibility in terms of the degree of head version and offset, as well as allowing more controlled stem positioning. Strains on the outer cortical bone surface have been shown to be strongly dependent on the orientation of a THA. These strains can be a potential cause for mechanical failure of the femur, and can lead to degenerative bone remodeling. The aim of the present study was to compare results from finite element models of a femur implanted with two cemented THA designs—a modular-neck and a fixed-neck.

METHODS:

Two physiological load cases were simulated in finite element (FE) models of a polished, cemented, modular-neck total hip stem (Profemur XM, Wright Medical Technology Inc., Memphis, USA). Four modular neck configurations were modeled: a short (41 mm) offset, an extended (50 mm) offset, an extended (50 mm) offset with a 14° anteverision, and an extended (50 mm) offset with 14° retroversion (Figure 1). The modular-neck device was compared to the Exeter stem (Stryker, Newbury, UK) (45mm offset) because this implant has an excellent long-term clinical outcome.

These geometries are referred to as Profemur-Short, Profemur-Extended, Profemur-Anteverted and Profemur-Retroverted. The geometry for the Exeter is referred to as the Exeter model. Results were also compared between these implanted models and the Intact femur model. The intact femoral geometry was derived from the CT dataset of a cadaveric femur and the CT numbers were converted into a realistic distribution of material parameters using relationships established by Rho [1]. The bone cement and implants were modeled as linear elastic. A Coulomb friction contact relationship was used to model the cement-stem interface. Contact parameters determined previously by comparing dynamically inducible micro motion results from an Exeter FE model with those measured using Roentgen Stereophotogrammetric Analysis were used.

The two physiological loading conditions were represented by applying muscle and hip contact loads simulating an instant at 10% of the gait cycle, when the abductors and adductors are active and stair climbing. For both load cases, boundary constraints were applied to the distal femur to restrict rigid body motion and to provide an approximation of the reaction forces from the tibia.

Principal strains on the outer, medial surface of the cortical bone were compared between the Intact, Profemur XM and Exeter models. Results for the peak and median principal stresses and strain energy distribution in the cancellous bone adjacent to the cement mantle were compared between the models. Peak principal stresses were compared with the ultimate strength of cancellous bone under tension and compression. Principal stresses in the cement mantle were compared between similar volumes of elements at the calcar and at the tip of the Profemur XM and Exeter implants. The magnitude of cement mantle stress was compared to the fatigue strength of PMMA bone cement, (10MPa).

RESULTS:

The variation and magnitude of principal strains along the medial cortical surface were similar in the Profemur XM and Exeter models (Figure 2) for the respective load conditions. For the stair climbing load condition the peak first principal stress in the Profemur XM models was up to 280% of the cement fatigue strength, and in the Exeter, the peak stress was 140% of fatigue strength. These peaks occurred at the proximal medial aspect of the cement mantle. The average stress was between 2-4% of the cement fatigue strength for all the FE models.

The average cement stresses at the calcar (Figure 3) and implant tip showed minimal variation between the modular-neck models and the Exeter for the two physiological load conditions, and were well below the fatigue strength of the cement mantle.

DISCUSSION:

It is anticipated that the modular-neck device will have a similar clinical performance to that of the Exeter, with the additional advantages of increased modularity. A long offset combined with neck retroversion should be avoided with patients that have a high body mass index.

REFERENCES: