BIOMECHANICS OF A STEMLess, METaphyseAL FIXATION FEMORAL DESIGN: EFFECTS OF SCREW FIXATION AND INTERFACE CONDITIONS

INTRODUCTION:
Bone conserving designs, such as hip resurfacings, are an alternative treatment option to conventional total hip arthroplasty (THA) in young, active patients. Previous studies have shown that medullary fixation can result in significant proximal bone resorption through stress shielding [1,2], while it has been suggested that hip resurfacing arthroplasty will load the proximal femoral bone in a more physiological manner [2,3]. Metaphyseal fixation has been proposed as a solution for preserving proximal bone stock, while minimizing bone resorption induced by medullary fixation [4]. The stemless Munting hip is an example of a design that relies on proximal metaphyseal fixation (Fig. 1) [4,5]. The hydroxyapatite-coated implant has no intramedullary stem and fits into an angular resection of the femoral neck. The component has five lamellae that fit into the metaphyseal cancellous bone, while two trans-trochanteric screws and a distal screw provide initial fixation in place of bone cement. Although in vitro experiments of the Munting hip have been performed previously [4], the effects of screw fixation and interface conditions have not been fully described. The goal of our study was to develop a three dimensional FE model of the implanted femur to examine the effects of screw fixation and bone-implant interface conditions on femoral stresses, strains, and remodeling and to determine if these data support the concept of metaphyseal fixation.

METHODS:
A 3-D finite element (FE) model of the natural femur was generated based on the geometry and density distribution of a 45 year-old female donor hip with no known bone disorder (IRB-approved). Computed tomography (CT) data were acquired of the pelvis together with a European Spine Phantom with an in plane resolution of 0.781x0.781 mm and a one 1mm slice interval. Linear brick elements were used to model the femoral trabecular bone (TrueGrid, XYZ Scientific Applications, Inc., Livermore, CA). The final mesh consisted of 150,120 brick elements and 10,176 shell elements, with 155,819 nodes (Fig. 2). Non-homogeneous, isotropic, linear elastic material properties were assigned to the trabecular bone based on the QCT data and reported density-modulus relationships [6].

A FE model of the femur implanted with the Munting hip was also constructed (52,983 brick elements and 3,780 shell elements, with 52,983 nodes) (Fig. 2). The Munting model was comprised of a rigid 28 mm femoral head and a Ti alloy femoral component. HA coating on the implant surface in contact with bone was represented by 100 micron thick shell elements. Four screw fixation conditions were examined by sequentially removing the distal screw, followed by the superior trans-trochanteric screw, and followed by the central trans-trochanteric screw (Fig. 3). Three bone-implant interface conditions were examined: fully fixed, fully loose, and platform fixed-screws loose ($\mu_p\tau_p=0.3$ for loose).

Clinically relevant femoral joint (2.4xBV) and muscle loads were applied to simulate peak joint loading during gait [7]. Femoral bone stresses (min. principal) and strains (von Mises) in the natural and implanted femurs were compared. Bone remodeling stimuli were also determined for the implanted femurs by comparing changes in strain energy relative to the natural femur.


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