INTERNAL BONE STRESS ANALYSIS OF TIBIAL IMPLANT WITH INCORPORATION OF SOFT TISSUES

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INTRODUCTION

Stress shielding at the proximity of total knee replacement (TKR) implants can cause of aseptic loosening and weakened implant fixation. Reduction of stress shielding is therefore a focus of current TKR design. A finite element (FE) tool was recently developed, improving upon the state of the art for stress analysis of the tibia. It addresses deficiencies of past FE models by giving special consideration to the incorporation of realistic geometry, material properties, and loading to provide improved analysis of bone stress states. A better representation of stress states in the post-TKR tibia will allow for better implant design. This paper presents a parametric analysis of the effects of TKR tibial component design on stress shielding.

METHODS

A 3D tibia, incorporating orthotropic and heterogeneous bone properties mapped directly from experimental data, was used. Loading representative of the stance phase of gait was applied. Tibiofemoral and patellofemoral surfaces were loaded with non-uniform distributed compressive forces while 4 ligament (ACL, PCL, MCL, LCL) and 6 muscle (gracilis, sartorius, semitendinosus, semimembranosus, popliteus, iliotibial tract) forces were distributed over experimentally determined attachment areas. The ACL and PCL were each divided into anterior and posterior bands; the MCL was divided into deep and superficial bands. The lines of action for each ligament and muscle were assigned for various intervals of the gait cycle. This realistic approach to incorporating loading conditions is rarely done in FE models.

The tibial TKR component, modeled after a commercially available implant, consisted of a metal tray, a polyethylene insert, and a post fixed to the tibia by bone cement. Three FE tibia implant models were created featuring a Ti6Al4V tray (E=117 MPa, ν=0.3), a CoCrM tray (E=220 MPa, ν=0.3), and a stainless steel (AISI 316 L) tray (E=200 MPa, ν=0.3). Cement-bone interface forces were examined for the models at 3 locations: beneath the tray, around the periphery of the post, and beneath the post. Stresses were compared with those from a model representing the natural tibia (with identical loading conditions) to examine the stress changes associated with introduction of an implant. Stress shielding was assessed by examining global changes in stress distribution and stress changes in the cancellous bone immediately surrounding the post.

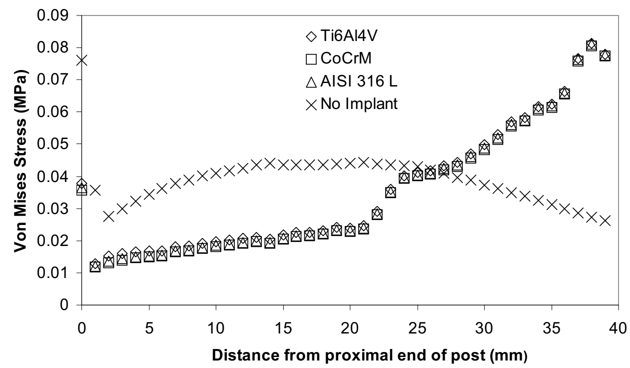

Figure 1: Stress in cancellous bone posterior to implant post from the proximal end to the distal end of the post.

RESULTS AND DISCUSSION

Introduction of a metal post generally reduced stress in the surrounding cancellous bone at the more proximal portion of the post and increased stress in the more distal portion (Fig 1). High stress increases were observed in the bone directly beneath the post. Globally, bone stress was seen to decrease in both cortical and cancellous bone (except in the proximal anterior bone). Inserting an implant into the tibia greatly reduced bone stress; the type of metal composing the tray component slightly affected stress levels in the cancellous bone. In addition, the interface forces between the bone and the cement used to secure the implant were not affected by the material composition of the implant (Table 1). In a previous work, it was found that the shape of the post had a noticeable influence on interface forces [1]. The presentation will discuss the influence of different post shapes and different implant materials on cement-bone interface forces and stresses distribution in the tibia.

CONCLUSIONS

While inserting a metal implant significantly alters the stress fields, the material composition appears to have only a slight effect.

REFERENCES

1. Au AG, et al. *Med Eng Phys* 27, 123-134, 2005.

Table 1: Load distribution of cement-bone interface forces for 3 different implant material types.

Interface	**Implant Metal**		
Location	**Ti6Al4V**	**CoCrM**	**AISI 316 L**
Beneath Tray	72%	73%	73%
Post Periphery	24%	23%	23%
Post Base	4%	4%	4%