EVALUATION OF BONE CEMENT AUGMENTATION IN PROXIMAL FEMUR

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INTRODUCTION

The prevalence of bone fractures increases markedly with age, which is correlated to osteoporosis, low bone mass and structural deterioration of trabecular bone. Infiltration of bone cement into vertebral bodies (vertebroplasty) has been shown to substantially increase the strength and stiffness of mechanically compromised trabecular bone. It was expected that a similar benefit might be realized in the proximal femur [Heini, et al, 2001]. Before clinical trials, the effects of this treatment technique should be investigated. The objective of this study was to investigate the effects of cement augmentation on the mechanical properties of the proximal femur. In the present paper, the relative effects of bone osteoporosis, femoral neck fracture and cement augmentation on the femur stiffness were evaluated using finite element simulations.

METHODS

A standardized femur (FE Mesh Repository, Istituti Ortopedici Rizzoli, Italia) was used as a basis for the finite element model of an intact femur (Figure 1). For simulating the osteoporosis effects on the femur stiffness, the Young’s modulus of the cancellous bone was reduced, which was assumed to be 20% of the normal bone tissue [Silva and Gibson, 1997]. Bone fracture effects were simulated using a crack inserted in only the top portion cortical shell of the femur neck, i.e. only halfway through the neck. When modeling bone cement augmentation, a cement mantle was placed within the femur geometry with its shape shown in Figure 1. A perfect bond between cement and bone was assumed in the analyses. In the finite element simulations, the distal section of the femur was fully restrained. The structure was loaded at the hip joint (femoral head) with 3 kN at an angle of 20° to the shaft of the femur. This loading corresponds to loads experienced by a person weighing 70 kg during normal walking [Akay and Aslan, 1996]. The properties of the normal bones (cortical bone and cancellous bone) and cement are shown in Table 1 [Lennon and Predergast, 2002]. The finite element models were generated using commercial software Hypermesh (Altair Engineering Inc., Troy, MI, USA) and analyzed with the finite element package ABAQUS (HKS Inc., Pawtucket, RI, USA).

Figure 1: Finite Element Model of Bone Cement Augmentation in Proximal Femur
### RESULTS AND DISCUSSION

The apparent stiffness of the proximal femur is shown in Figure 2 for several conditions, normal, fractured, and osteoporotic. For comparison, all the data were normalized with respect to the intact normal femur.

![Figure 2: Apparent Stiffnesses of the Femur](image)

(N: Normal Bone Femur; F: Neck Fracture Femur; O: Femur with Osteoporosis Bone; OP: Femur with Neck Fracture and Bone Osteoporosis)

It is seen that femur stiffness with cement augmentation increased by 2.9%, 2.9% and 6.2% in normal bone, fractured bone and osteoporotic bone, respectively. This clearly demonstrates the efficacy of cement augmentation in reinforcement of the proximal femur. When the reinforced bone is osteoporotic, the stiffness of the femur was only 96% of the intact normal femur. This indicates that augmentation is not a replacement for bone loss and that prevention of bone loss is still desirable. Although the introduction of a partial neck fracture decreased the stiffness less than bone osteoporosis, it is expected that high stresses will occur near the neck fracture region, which will decrease the strength of the femur. Lastly, cement augmentation in the neck definitely improved stiffness in all cases and helps to reduce the concentrated stress around a fracture, which will likely strengthen the femur.

### SUMMARY

The effects of bone cement reinforcement on femur stiffness were evaluated with three dimensional finite element analyses. This study shows that bone cement treatment is able to reinforce the osteoporotic femur and the neck-fractured femur. This is a preliminary study; further investigations are needed to provide more in-depth examinations before clinical application of cement reinforcement of the proximal femur is considered.

### REFERENCES


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