EFFECT OF PROSTHESIS DIMENSIONS ON THE STRESSES OF AN ELBOW JOINT PROSTHESIS

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Introduction

Hip joint and knee joint replacements are very common nowadays compared to elbow joint replacement. So a lot of research has been done to study hip and knee joint replacement, and rarely on elbow joint replacement. This paper focuses on the effects of change of prosthesis dimensions (length and radius of the stem) on the internal stresses developed in the bone and stem due to static loading conditions. The use of finite element method (FEM) in the analysis of stresses in orthopaedic biomechanics has the potential of giving solutions that take into consideration the complexity of the system (Huiskes, Chao, 1983, Brekelmans et al., 1972, Prendergast, 1997), and hence has been used in this endeavour.

Materials and Method

In order to study the effects of changes of the dimensions of the prosthesis stem on the internal stresses of the stem and bone, a 270 mm long hollow cylindrical finite element model of the ulna of uniform cross section fitted with a prosthesis stem as shown in figure 1 was used in the analysis for internal stresses. Eight node isoparametric solid elements having linear elastic, homogenous, isotropic material properties were used in this model. Material properties used are given in table 1. The modeling and analysis was done using the general purpose finite element analysis software; SAP2000. The loading and the boundary conditions were kept unchanged while the geometry of the prosthesis stem was changed to study the effects of the change on the stresses in the bone and in the prosthesis stem.

Table 1. Material properties used in the model

Component	Young's modulus, E / (GPa)	Poisson's ratio, υ
Cement	2	0.3
Bone	20	0.3
Stem	200	0.3

The interfaces between the bone, cement, stem materials were modeled to be fully bonded. The proximal end of the stem was fixed and the bone was loaded with a force simulating a weight of 50 N in the hand with the elbow flexed at 90 degrees. The corresponding force in the brachialis muscle was calculated using simple statics and was applied at a distance of 20 mm from the proximal end of the stem. The length from the elbow joint to the distal end of the ulna was assumed to be 300 mm. The fixed support at the proximal end of the stem was modeled at a length of 10 mm from the elbow joint thereby describing the total length from the proximal end to the distal end of the model to be 290mm. Note that in figures 2 to 5 'x' is measured longitudinally from the elbow joint towards the distal end of the stem.

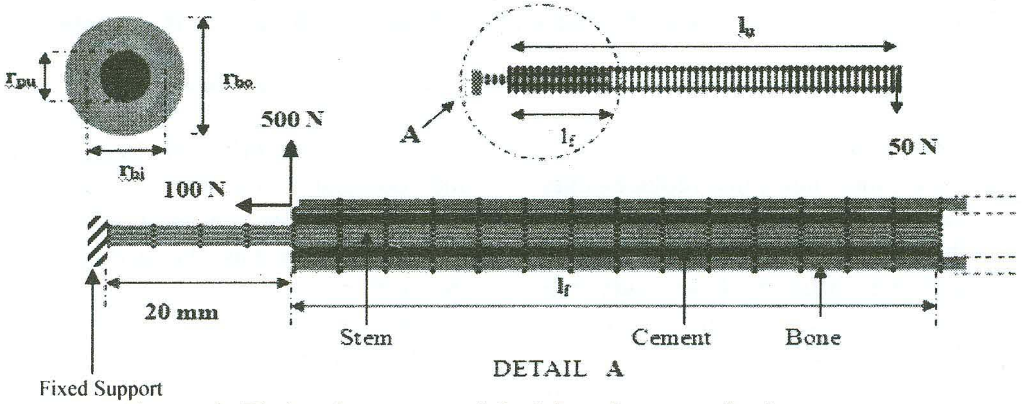

Figure 1. Finite element model of the ulna-prosthesis system

Results

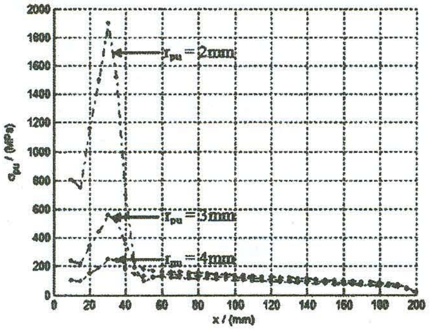

Figure 2. Variation of bending stress at prosthesis top fiber with radius of the stem

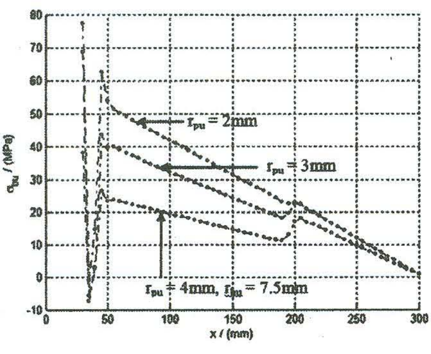

Figure 3. Variation of bending stress at bone top fibre with radius of the stem

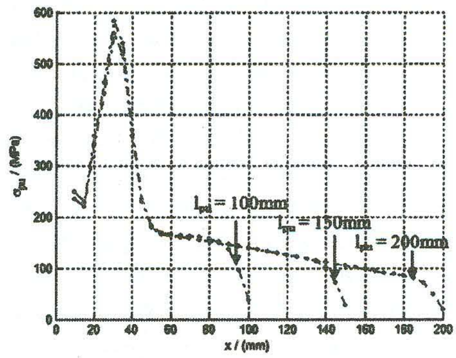

Figure 4. Variation of bending stress at prosthesis top fiber with length of stem

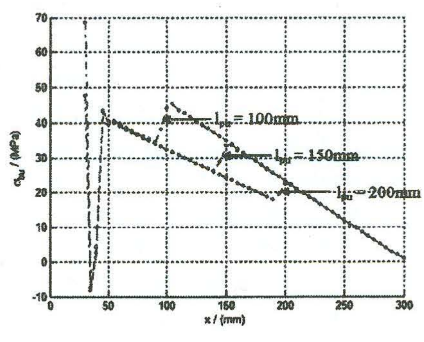

Figure 5. Variation of bending stress at bone top fiber with length of the stem

Discussion

It was found that the maximum stress concentration in the bone as well as the prosthesis occurs at the proximal end of the prosthesis stem and reduces with the increase in the radius of the stem cross section. The stresses along the length of the stem are more or less the same. The longitudinal stress in the bone top fiber reduces with increasing stem radius. This indicates that due to the increase of stiffness of the stem the bone is shielded and only a portion of the total load is carried by bone.

Variation of the length of the prosthesis has little effect on the longitudinal stress in the stem top fiber and the reduction in prosthesis length was found to have a positive effect on the longitudinal stress in the bone top fiber since it reduces the effect of stress shielding and makes the top fiber stress distribution more natural.

Conclusions

Results of the study illustrate the relationship between the dimensions of the ulna component of an elbow joint implant and bending stresses developed in the ulna bone and prosthesis stem due to static loading in elbow flexion.

The same analytical procedure used to analyze the bending stresses in the ulna component in this study can be used to analyze the stresses with variation of the shape of the ulna component. The same procedure can also be adopted to study the stresses in the humeral component.

References

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