FINITE ELEMENT PARAMETERS AFFECTING MICROMOTION AND STRAIN ENERGY DENSITY PREDICTIONS IN TIBIAL MODEL AS DETERMINED BY FACTORIAL ANALYSIS

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INTRODUCTION

The population group receiving total knee replacements is being extended to both older and younger patients, which has lead to an increase in the number of surgeries performed each year. Between 1991 and 2000 the number of surgeries doubled (Dixon et al. 2006), which will lead to an increase in revision total knee arthroplasties (rTKAs) even as the failure rate decreases. Generally, tibial implants with stem extensions are used to increased implant stability and transfer loads away from the weak proximal tibial bone. Yet, surgeons performing rTKAs are faced with many decisions including the mode of fixation, stem diameter, length, and geometry. In order to maximize the survival rates of the implant, the effects of these stem configurations on implant stability and bone loading need to be quantified. Therefore the goal of this study was to quantify the effects stem length, load distribution, and friction coefficient have on the micromotion and proximal bone strain energy density (SED) in a finite element (FE) model of a tibial bone with a revision tibial implant.

METHODS

A FE model of the tibial bone and rTKA component (Zimmer, Warsaw, IN) was created using a previously defined computed tomography (CT) to FE protocol (Schmidt et al. 2006). Two 2^3 unreplicated factorial analyses were performed on three factors: stem length, bone-stem friction coefficient, and medial to lateral compartment load distribution. The low and high levels of the friction coefficient represent smooth and rough surface finishes, respectively. A 60:40 load distribution represents normal knee joint loading, whereas, 100:0 represents a varus deformity. The high and low states of each factor are shown in Table 1. The first analysis considered maximum bone-stem micromotion, while the second analysis evaluated average SED in the proximal 20 mm of the tibial bone. All statistics were performed using MiniTab.

Table 1: Factors and Levels

Factor	Level	
	–	+
A. Stem Length	145 mm	200 mm
B. Friction Coefficient	0.1	0.4
C. Load Distribution	60:40	100:0

RESULTS AND DISCUSSION

As seen in the normal probability plot, friction coefficient and load distribution significantly affected proximal SED since they did not lie near the line (Figure 1). Similarly, Figure 2 shows all three main factors (stem length, friction coefficient and load distribution) had a significant effect on maximum micromotion. In general, maximum micromotion increased with either increased stem length or normal knee joint loading, while average proximal SED increased with varus load distribution.

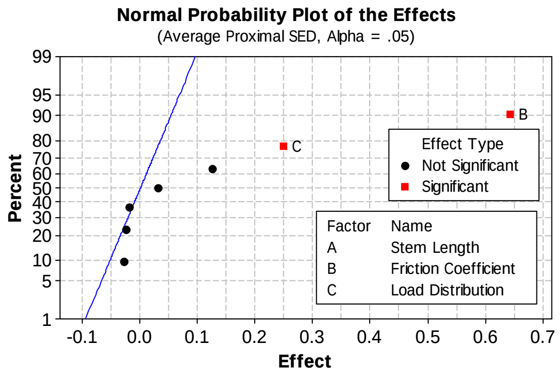

Figure 1: Normal probability plot of effect from proximal SED data.

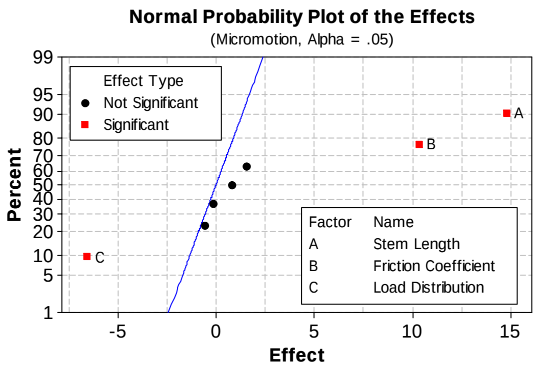

Figure 2: Normal probability plot of effect from micromotion data.

Figure 3 shows no interaction between factors when considering micromotion. Two distinct trends can be seen in the results for proximal bone SED. The first trend is, with a stem-bone friction coefficient of 0.1, a change in stem length had no effect on proximal SED. Second, there is an interaction between load distribution and stem length.

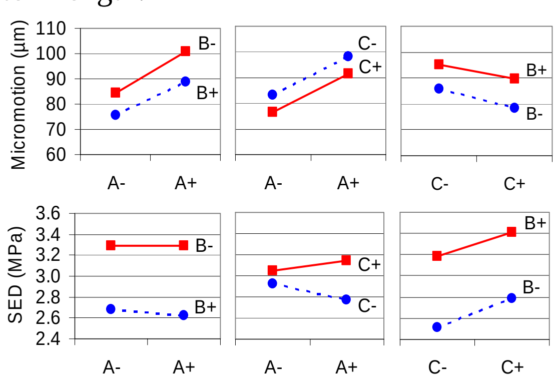

Figure 3: Factor interaction plots of stem length (A), friction coefficient (B) and load distribution (C).

SUMMARY/CONCLUSIONS

This study provided initial steps in developing an accurate FE model of the tibial component to better understand the parameters that affect implant stability and bone loading after an rTKA. In addition, it has shown factorial analysis combined with FEA can be a valuable tool to perform parametric studies. The statistical analysis provided information about which boundary conditions have the most significant effect on the results of the model. This study showed friction coefficient has a significant effect on both micromotion and SED results; and therefore, efforts need to be directed towards in-vitro testing to quantify this parameter more accurately. Load distribution also affected both results, thus offering encouragement to investigate the effect of this parameter in other regions of the model, such as stress at the stem tip. Finally, the information obtained from the interaction plots led to the conclusion that proximal tibial bone loading was not affected by stem length when a smooth stem was used. In contrast bone loading decreased when a long stem with high surface roughness was used, when compared to a short stem.

REFERENCES

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