Design and Analysis of Robust Total Joint Replacements: Finite Element Model Experiments With Environmental Variables

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Computer simulations of orthopaedic devices can be prohibitively time consuming, particularly when assessing multiple design and environmental factors. Chang et al. (1999) address these computational challenges using an efficient statistical predictor to optimize a flexible hip implant, defined by a midstem reduction, subjected to multiple environmental conditions. Here, we extend this methodology by: (1) explicitly considering constraint equations in the optimization formulation, (2) showing that the optimal design for one environmental distribution is robust to alternate distributions, and (3) illustrating a sensitivity analysis technique to determine influential design and environmental factors. A thin midstem diameter with a short stabilizing distal tip minimized the bone remodeling signal while maintaining satisfactory stability. Hip joint force orientation was more influential than the effect of the controllable design variables on bone remodeling and the cancellous bone elastic modulus had the most influence on relative motion, both results indicating the importance of including uncontrollable environmental factors. The optimal search indicated that only 16 to 22 computer simulations were necessary to predict the optimal design, a significant savings over traditional search techniques.