PROJECT SUMMARY

This CAREER proposal seeks to develop an integrated educational and research foundation in computational modeling of artificial knees. The two main objectives are (1) develop a virtual prototyping environment that can be used to improve wear and functionality in artificial knees, and (2) create two exhibits on engineering analysis of knee function for the largest science museum in the southern U.S.

(1) Intellectual Merit of the Proposed Activity

Current experimental and computational methodologies for studying total knee replacement (TKR) functionality and wear have significant limitations. Knee simulator machines used to measure wear are costly and time consuming, while dynamic finite element methods that predict motion and contact pressures simultaneously require hours or days of CPU time. Consequently, neither is appropriate for design sensitivity and optimization studies of knee implant design and surgical positioning issues. Furthermore, neither allows the study artificial knee function within the in vivo loading environment of the larger musculoskeletal system.

This study proposes a fundamentally new approach for studying TKR functionality and wear. The approach integrates elastic contact theory with multibody dynamics theory to produce a hybrid simulation environment that possesses the advantages of both – fast dynamic movement simulation from multibody dynamics and accurate contact pressure prediction from elasticity. The method is fast enough to be integrated into a larger dynamic systems model of the musculoskeletal system, providing a unique in vivo computational environment for virtual prototyping of artificial knees. The environment will be extensively evaluated in four stages against existing and new experimental data to ensure that the final product is predictive.

Paralleling these activities is the development of two exhibits on knee mechanics for the Museum of Science and Industry in Tampa, FL. The exhibits will take the engineering concepts and methods investigated in the research plan and make them accessible to the general public. One exhibit will be a bank of knee models that visitors can manipulate to study natural, injured, arthritic, and artificial knee mechanics, and the other will be a multimedia exhibit at which visitors can create and analyze simple knee models using the same engineering software as in the research plan. Minority and economically disadvantaged children participating in museum programs will serve as exhibit evaluators to expose them to the use of engineering in medicine.

(2) Broader Impacts Resulting from the Proposed Activity

Anyone who has suffered a knee injury is at increased risk for developing osteoarthritis (OA) in later life. Most of us know at least one person (possibly even we ourselves) who is or will be a candidate for TKR surgery, now the number one joint replacement surgery performed in the U.S. An estimated 375,000 TKRs will be performed here in 2002, and if current trends continue, over 10 million will be performed on Americans alone between now and the year 2020. The ability to improve the longevity and functionality of these implants would make a significant impact on the quality of life for the millions of knee OA sufferers worldwide who will receive knee replacements in the coming years.

The educational plan will have a broad impact on two fronts. Dissemination of the research concepts and methods to the general public through the science museum will benefit thousands of visitors annually. In addition, exhibit evaluation activities and a coordinated recruitment plan will involve K-12, women, and minority students with the proposed research methodologies.