Name(s)
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Project Number
S0317

Project Title
Design and Mechanical Analysis of a Promising Hip Prosthesis Using Quaternions

Abstract

Objectives/Goals
Conventional ball-and-socket hip prostheses suffer from challenges that include painful dislocation requiring surgical revision, material wear, and bio-contamination from wear particles leading to bone loss and prosthesis failure. A new hip prosthesis design to address these problems has been developed, modeled mathematically, and tested in a laboratory framework.
The first objective of the study is to analyze and validate the improved movement range of the new, patent-pending hip prosthesis design employing a gimbal or universal joint. A second objective is to determine load-carrying capacity and predict durability under day-to-day loading.

Methods/Materials
The investigation, modeling and analysis and validation of both joint motions and forces has been performed both using a hand-made physical model with an instrumented skeleton and test frame and through a computer using the Mathematica(R) Language with conventional Eulerian Angle transformations and Quaternion approaches.

Results
Adding not just one but two rotational bearings to a standard Universal joint is found to create an extra degree of rotational freedom enabling a greater range of motion. The extra rotation comes into play when the U-joint nears a position when the three rotational axes lose their linear independence - a condition termed gimbal lock in the mathematics and aerospace vocabulary.

Conclusions/Discussion
The ability of the U-joint prosthesis to operate smoothly and safely with adequate range of motion, last indefinitely due to minimal friction U-joint designs, maintain isolation from the body to reduce possible infection of the joint, and not be dislocated shows potential improvement over existing prostheses and worthy of future study and clinical experimentation. The durable design may find applications to other joints of the body, including shoulder and knees.

Summary Statement
Building from my previous year's research that investigated a new hip prosthesis design using a Universal/gimbal joint, this year's study analyzed (Eulerian Angle transformations and Quaternion approaches) how this new hip prosthesis design

Help Received
I received verification of the unique prosthesis design from Dr. Rama Chandran, an orthopedic surgeon. My father helped supply tools and guidance in building the test frame for a part of the study.