Design and Mechanical Analysis of a Promising Hip Prosthesis Using Quaternions

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The study’s first objective is to analyze and improve movement range of a new hip prosthesis design using a gimbal or universal joint. A second objective is to determine load-carrying capacity and predict durability under day-to-day loading. Gimbal behavior is compared to a conventional ball-and-socket hip replacement. Interestingly, this research addresses problems in aerospace navigation -- as the re-entry tumble of Apollo 13 caused its gimbaled gyros to reach lock-up limits and cause disorientation. The investigation, modeling and analysis and validation of both joint motions and forces was performed both using a hand-made physical model with an instrumented skeleton and test frame, and through computer using the Mathematica(R) Language with conventional Eulerian Angle transformations and Quaternion approaches. Adding not just one but two rotational bearings to a standard Universal joint was found to create an extra degree of rotational freedom enabling 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. The U-joint prosthesis’ ability 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 worthwhile future study and clinical experimentation.

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