A New Approach to Micromotion Characterization of Modular Tibia Implants

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Introduction: A major concern in the use of modular knee implants has been particle generation from the backside of the UHMWPE tibial insert. Motion, commonly referred to as micromotion of the tibial insert against the proximal tibial tray can generate microscopic particles that with time can propagate throughout the joint and lead to osteolysis, a disease that promotes bone resorption and finally, implant loosening [1,2]. This study was undertaken to develop a simple and sound approach to characterizing modular knees that could be easily reproduced in any orthopaedic laboratory having a 2-axis test machine.

Materials and Methods: Six competitive products; Optetrak n=(1) (Exactech, Inc., Gainesville, FL 32653), NexGen (3) (Zimmer, Inc., Warsaw, IN 46581), Journey (1) (Smith & Nephew, Memphis, TN 38116), Advance (1) (Wright Medical, Arlington, TN 38002), Scorpio (1) and Duracon (2) (Stryker, Kalamazoo, MI 49002) were tested along with 2 DePuy products, PFC Σ GVF (5) and XLK (5) with i2 locking mechanism (DePuy Orthopaedics, Warsaw, IN 46581). A variety of insert locking techniques were employed across the samples. All specimens were taken from sealed packages.

Trays were cemented in appropriate potting fixtures using Ultracryl II epoxy (Masel, Bristol, PA 19007) and allowed to cure before milling 2 holes in insert for a multi-directional load applicator. Holes were positioned such that the force will be applied at 0.050 inches from the tray/insert interface about the insert center of rotation. Each construct was soaked in a 37C RO water bath for a minimum of 12 hours before testing.

Testing was conducted on an MTS 858 Bionix servo hydraulic test frame with TestStar IIm controller utilizing MPT software. Micromotion was measured using a Heindenhain model ST 1278 encoder fixed to a custom encoder fixture mounted to the tray fixture. A laptop computer equipped with a custom MatLab (MathWorks, Inc., Natick, MA 01760) v7.2.0.232 data acquisition program was used to acquire the encoder data. Microsoft Excel 2000 was used to analyze and plot the micromotion data. The measurement system has resolution of ± 0.5 micrometers.

A 0-N (Newton) compressive load was maintained for all test directions. The A/P micromotion test applied a 100-N anterior load through the holes in the tibia insert and reversed to a 100-N posterior load, and returned to the 0-N load position.

Micromotion was defined as the measured displacement between the minimum and maximum load positions.

Micromotion was identical to the A/P micromotion loading except the tibial tray/insert assembly and load applicator was rotated 90 degrees.

For rotational measurements, a mark was placed on the insert to identify the measurement location of the encoder. The x-y coordinates of this point with respect to the insert rotational center needed to be determined to provide inputs for the angular micromotion calculation. This work was conducted on the Bridgeport mill in the machine shop equipped with a digital indicator, catalog 387538400 (Accu-Rite Companies, Inc., Jamestown, NY 14701). Equations were derived to solve for the angle of rotation, theta, given the measured amount of linear micromotion, m., and the x-y location of the encoder. A MatLAB Version 7.2.0.232 (r2006a) program was written to solve for angle where the two equations were equal.

For the RT micromotion test, the rotational orientation of the load applicator was used to apply a 1-N-m ramp torque to the insert in the counter-clockwise direction, followed by a 6-N-m ramp torque in the clockwise direction.

Results: AP, ML, R, and RT micromotion was characterized for each specimen. “R” is a compilation of the AP and ML micromotion and was calculated by taking the square root of the sum of the squares of AP and ML.

Standard deviation was calculated for each sample, where applicable, and ranged between 0% and 47% of the mean.

Discussion: Measurement capability appears to range from constructs demonstrating extremely small micromotion to those exhibiting macromotion. A sample of 3 specimens was completely characterized within about an hour. This approach has the advantage over contemporaries [3,4] by actuating the insert while avoiding insert clamping that can over-constrain and distort the insert. It features fixtures of limited complexity with greater stability through rigid fixture clamping. The Heindenhain encoders present a great improvement in accuracy over other measurement devices.

Some of the weaknesses of this method would include potential specimen-to-specimen errors, as the encoder placement was approximate with respect to the insert. A fixture design is currently underway that will integrate encoder mounting to the tray fixture and the fixture will allow to swap tray/insert constructs between tests, eliminating repeated setups. The design of the fixtures will also be specific to the product and size allowing for tight tolerances around the tray periphery, further improving repeatability and save time in the overall characterization process.

The addition of a second encoder would also be helpful during AP and RT testing to understand the pre-test position of the insert with respect to the tray but probably wouldn’t improve the overall measurements.