Analysis of Wear Patterns in Retrieved Polyethylene Tibial Inserts Using Micro-computed Tomography

+1Teeter, M G; 2Brandt, J-M; 3Naudie, D D; 4Bohn, E R; 5McCalden, R W; 6Holdsworth, D W
+1The University of Western Ontario, London, ON, 2Concordia Hip and Knee Institute, Winnipeg, MB 3London Health Sciences Centre, London, ON
mteeter@imaging.robarts.ca

Introduction

The use of micro-computed tomography (micro-CT) for quantifying wear in polyethylene (PE) components from joint arthroplasty has recently been described [1]. Micro-CT enables the construction of three-dimensional maps of surface deviations across the entire PE component geometry, in addition to measurements of volumetric changes [1]. Although a number of studies have been published demonstrating excellent patient outcomes for the Genesis II implant (Smith & Nephew, Memphis, TN), as well as one retrieval study that found little evidence of severe surface damage on the components using a semi-quantitative grading system, the amount of volumetric changes occurring on the PE insert in vivo due to both wear and creep has not been reported for retrieved Genesis II components [2,3]. The aim of this study was to use established micro-CT techniques to quantify three-dimensional surface deviations due to wear and creep in retrieved PE inserts of the Genesis II total knee replacement.

Methods

Twelve Genesis II PE tibial inserts retrieved between 1999 and 2010 at our two institutions were examined. All inserts were of posterior-stabilized (PS) design, size 3-4 and 11 mm in thickness. The patients were female in all cases, with a mean BMI of 34.5 (range 25.9-40.8). Most patients were impianted on the right side (ten of 12) and were primarily revised for infection (nine of 12). The mean duration of implantation was 25 months (range 0.5-78). Each PE insert was scanned with a dedicated laboratory micro-CT scanner (eXplore Vision 120, GE Healthcare, London, ON) at 50 µm isotropic voxel spacing, and their 3D surfaces were generated in a previously described manner [1].

A previously developed software utility was used to iteratively co-align the insert geometries and calculate surface deviations in µm [1]. The scanned volumes of the five new, never-implanted PE inserts were averaged to construct an idealized reference geometry to represent the unworn state of the retrieved PE inserts. Subsequently, the 12 retrieved PE inserts were each co-aligned to the reference geometry, the three-dimensional surface deviations between the two geometries were calculated, and a map with these deviations was generated. Each deviation map was visualized in ParaView (Kitware Inc., Clifton Park, NY). Patterns of deviations on the articular and backside surfaces of the PE inserts were examined simultaneously under careful macroscopic inspection and using the deviation maps of the PE insert surfaces. The observed deviations were classified into diffuse regions (damage features such as burnishing and striations) and focally defined regions (damage features such as macroscopic pitting and abrasions). Deviations were examined using the software’s probe location tool, which displayed the exact quantity of deviation within a region specified by the user. Six probe points, each with a radius of 1 mm, were placed within the identified regions at the location of the greatest deviation. The mean deviation between the six points was recorded.

Results

The majority of deviations were classified as diffuse regions from burnishing and striations, although focal damage features such as pits were also prevalent (Figure 1). Backside damage not attributable to the retrieval process consisted of slight burnishing that was observed macroscopically on 6 of 12 inserts, and corresponded to a minimal change in the appearance of the PE insert surface that was not reliably quantified using micro-CT. We therefore did not include backside wear in the analysis. However, macroscopic agreement was observed between the insert articular surfaces and micro-CT derived deviation maps.

Within the regions of the greatest diffuse deviations on the articular surface, the mean deviation was 91 ± 61 µm medially and 83 ± 62 µm laterally. No significant difference was found between the medial and lateral sides (p = 0.59). The greatest deviations (264 µm medially and 231 µm laterally) were found within the diffusely deviated regions of an insert that had been in vivo for 52 months. The mean deviation within the various pits was 78 ± 52 µm. There was no significant difference between the deviations in the diffuse regions and those within the pits (p = 0.65). The mean articular deviation rate for inserts in vivo for greater than one year was 50 µm/year, decreasing to 25 µm/year for inserts implanted for at least four years. The deviation rate was 422 µm/year for those inserts in vivo for less than one year.

Discussion

Overall, the pattern of wear varied between PE inserts. Aside from diffuse deviation patterns from burnishing, pitting was also seen on nine of the 12 inserts. The deviation rate dropped rapidly from time of implantation to one year, with most of those deviations possibly attributable to an initial creep response. Minimal backside damage was macroscopically observed, and the damage that did exist was below a level reliably quantifiable using the micro-CT technique. Azzam et al. [4] found significantly lower backside damage in retrieved PE inserts that used a peripheral locking mechanism and were sterilized with ethylene oxide (including the Genesis II).

Heyse et al. [3] noted generally low damage scores overall, with most damage features being burnishing, scratching, and pitting, without any delamination. This was consistent with this present study, assuming a linear relationship between the three-dimensional surface deviations and the semi-quantitative damage scores. A low damage score for the Genesis II PE inserts could be related to the use of ethylene oxide for sterilization amongst other factors. Tibial inserts sterilized with ethylene oxide have been found to have significantly lower damage scores than those sterilized with gamma radiation [4]. The surface deviation rate (due to wear and creep) for the Genesis II found in this study is on the low end of wear rates reported in the literature for other fixed and mobile total knee replacements, which range from 46 to 350 µm/year [5]. The relatively low surface deviation rate found in this study correlates with the good clinical outcomes (greater than 95 percent survivorship at ten years) found in previous studies for this implant [2].

References