Damage Scoring of Retrieved UHMWPE Tibial Inserts After Re-melting Reduces Error Due to Viscoelastic Effects

Introduction: Damage scoring of tibial inserts retrieved from revision TKA is commonly used as an indirect measure of articular and backside wear [1], but actually measures both viscoelastic deformation (creep) as well as physical damage from adhesive and abrasive wear [2]. The purpose of this study was to evaluate articular and backside damage of retrieved tibial inserts before and after re-melting, utilizing the “shape memory” property of UHMWPE [3] to reduce the influence of creep, thus more accurately measuring damage due to wear processes. We hypothesized that re-melting would significantly decrease damage score on the articular and backside surfaces due to the recovery of viscoelastic deformation.

Materials and Methods: A total of 26 UHMWPE tibial inserts were included in this study, including 20 specimens analyzed in previous studies [4,5]. All of the inserts were EtO-sterilized Profix Conforming designs (Smith & Nephew Orthopaedics, Inc.) that had locked into titanium alloy trays and articulated against cobalt-chromium alloy femoral components in vivo for an average of 3.8 years (range 0.096-13.4 years). The inserts were first evaluated for articular and backside damage prior to melting using a modified damage scoring method [1,6]. Damage was assessed in each 7.62 mm square on a scale from 0 (no damage) to 3 (damage > 50% area). Modes of damage were separated into three categories based on severity: light (burnishing, light scratching, light pitting), medium (scratching, heavy pitting, and gross deformation) and heavy (delamination and subsurface cracking), with damage multipliers of x1, x2, and x3, respectively. To allow the comparison of different size components, damage score was converted to a % maximum possible damage score (% max. DS) then correlated linearly to age in vivo.

The inserts were then heated in a vacuum oven above the melting point of UHMWPE (about 145 °C) to activate the shape memory property of the polymer. They were allowed to cool under vacuum and were re-scored by the same observer. The difference between pre-melt and post-melt % max. DS was calculated for both the articular and backside surfaces, using linear and nonlinear regression and paired t-tests with p < 0.05 for significance.

Results: All 26 tibial inserts exhibited articular surface damage before melting, while only 11 exhibited backside surface damage. None of the specimens exhibited heavy wear modes (delamination, subsurface cracking) on either surface, and only burnishing was found on the backside. After re-melting, the size of the worn areas was significantly reduced on the articular (p < 0.0001) and backside (p < 0.01) surfaces from the recovery of flattened machining marks. In addition, the depth and width of other surface features such as scratches were reduced or eliminated. Significant linear correlations between % max. DS and age in vivo were observed for both the pre-melt and post-melt articular (p < 0.0001; Figure 1) and backside surfaces (p < 0.001; Figure 2). Re-melting significantly reduced articular damage score (p < 0.0001) and backside damage score (p < 0.01) by an average magnitude of 28% and 25%, respectively. When plotting % change in DS vs. age in vivo, % change in articular surface DS decreased logarithmically with age in vivo (r² = 0.46; Figure 3), while % change in backside surface DS increased linearly with age in vivo (r² = 0.17, p = 0.35; data not shown).

Discussion: Surface damage of tibial liners is proportional to wear particle volume [7] but also includes viscoelastic deformation. As in previous studies [2,8,9], re-melting the inserts significantly reduced surface damage caused by viscoelastic deformation. On the articular surface, creep appears to be the primary damage mechanism initially, as the two specimens retrieved less than 6 months after implantation recovered all articular surface damage after melting. Specimens that had been implanted for more than 6 years recovered progressively less articular surface damage after melting, suggesting that abrasive and adhesive wear is the primary long term damage mechanism. While only 11 of 26 specimens exhibited damage on the backside surfaces, using linear and nonlinear regression and paired t-tests with p < 0.05 for significance, re-melting also significantly reduced backside damage, implying that some of the apparent burnishing damage observed was actually flattened machining marks that were recovered during the melt.

To the best of the authors’ knowledge, this is the first study to use the shape memory phenomenon on retrieved UHMWPE tibial inserts to evaluate the contribution of creep to surface damage over time. Re-melting the inserts significantly reduced articular and backside surface damage, allowing a more accurate measure of surface damage due to wear by reducing apparent damage due to creep.

References: