Comparison Between Gravimetric Wear and Wear Scar Size from Tibial Inserts Tested in a Knee Simulator

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Introduction: Damage scoring [1] and photogrammetry methods [2] have been used to assess surface damage of retrieved tibial inserts, but damage is a combination of both creep and wear processes [3]. Surface damage has been shown to be proportional to wear particle production [4], and while re-melting of retrieved tibial inserts can reduce error due to creep [5], articular damage is not the same as wear. The purpose of this observational study was to correlate gravimetric wear of tibial inserts tested in a knee wear simulator with the size of the wear scar on the articular surface, and determine whether the data is best represented by linear or nonlinear regression.

Materials and Methods: Cast CoCrMo alloy femoral components and tibial inserts made of non-cross-linked UHMWPE (Symmetric; Signal Medical Corp.) were donated for testing in a six-station knee wear simulator (AMTI). One side (three wear and two load/soak stations) tested stock tibial inserts locked into a stock tibial tray, while on the other side the backside of the inserts was modified with a dovetail allowing them to be locked for testing but easily removed to measure gravimetric wear.

Wear tests were performed at a frequency of 1 Hz using the ISO displacement-controlled protocol (ISO 14243-3). A solution of 25% bovine serum with 20 mM EDTA and 0.3% sodium azide was used as a lubricant. The test was paused periodically to measure gravimetric wear of the dovetailed inserts, corrected by the fluid absorption of the load/soak stations. Gravimetric wear of the stock tibial inserts was only measured at the end of the test (5M cycles). Because of the homogeneous nature of the wear scars, photogrammetry [2,6] was used rather than damage scoring, and the size of each wear scar was expressed as a percentage of the articular surface area [7]. The relationship between gravimetric wear and the size of the wear scar was evaluated by GraphPad Prism software.

Results and Discussion: Through 3M cycles, gravimetric wear was linearly correlated to the number of wear cycles ($r^2 = 0.79$, $p = 0.0001$), with a slope of 4.9 mg/Mc and a y-intercept near zero as expected (Figure 1). The slope (wear rate) was similar to that reported by others [8,9], but was less than a quarter of the wear rate measured by Ezzett et al. [10], probably reflecting differences in the serum dilution and waveform used.

The size of the wear scar increased with the number of wear cycles (Figure 2), with a significant linear relationship ($r^2 = 0.95$, $p < 0.0001$) and a slope of 3.5%/Mc but a y-intercept of 12.9%. Plotting the wear scar size as a function of gravimetric wear (Figure 3), a 2nd-order polynomial provided a significantly better fit ($r^2 = 0.95$, $p = 0.003$), although simple linear regression was also appropriate ($r^2 = 0.86$, $p < 0.0001$), with no significant deviation from linearity ($p = 0.18$). Previous work found a linear relationship between articular damage of retrieved tibial inserts and time *in vivo* [11], but the current study suggests a nonlinear fit may be better.

Conclusions: The knee wear simulator data suggest a nonlinear relationship between gravimetric wear and the size of the wear scars, and it must initially be nonlinear in order for the curve to pass through the origin. However, a linear relationship may be appropriate for the latter part of the curve. Future work will include measurements up to 5M cycles, and comparison between gravimetric wear and scar size of the stock tibial inserts at the end of the test.

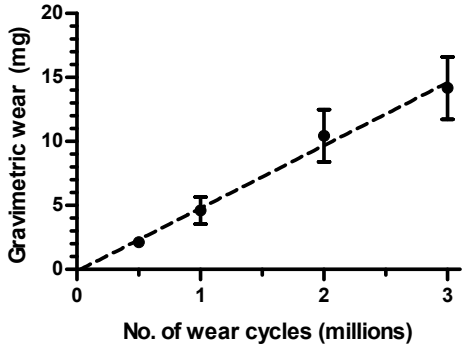

Figure 1. Plot of gravimetric wear as a function of the number of wear cycles, with its linear regression line.

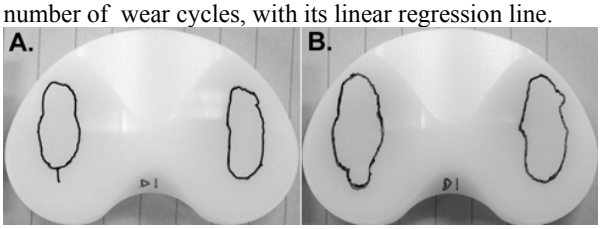

Figure 2. Scaled photographs illustrating the size of a tibial insert's wear scar after **A.** 1M and **B.** 3M cycles.

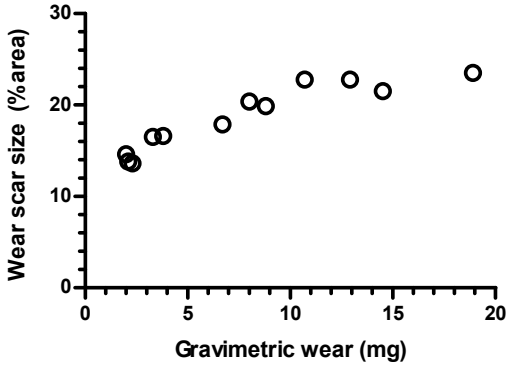

Figure 3. Plot of wear scar size (% of articular surface area) as a function of gravimetric wear for each insert.

References: 1) Hood et al., *JBMR* 17:829, 1983. 2) Grochowsky et al., *JBMR* 79B:263, 2006. 3) Muratoglu et al., *J Arthroplasty* 18:42, 2003. 4) Hirakawa et al., *J Arthroplasty* 14:165, 1999. 5) Uffelmann et al., *Trans 56th ORS* 0171, 2010. 6) Azzam et al., accepted for publication, *J Arthroplasty.* 7) Willie et al., *JBMR* 85B:114, 2008. 8) D'Lima et al., *CORR* 392:124, 2001. 9) Spector et al., *JBJS* 83-A(Suppl 2):80, 2001. 10) Ezzett et al., *CORR* 428:120, 2004. 11) Greulich et al., *Trans 55th ORS* 2351, 2009.