Alternative Sample Preparation Method for the UHMWPE Orthopedic Biomaterial Small Punch Test

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Statement of Purpose: This work outlines an alternative preparation methodology for manufacturing small punch test specimens from ultra high molecular weight polyethylene (UHMWPE). In the late 1990s, effort was directed towards the adoption of a standardized miniature specimen test for UHMWPE used in surgical implants. In addition to the more appropriate size of the miniature disk specimens, the multi-axial loading of the *in vivo* environment is better mimicked with a biaxial test. The result of this test standardization effort for UHMWPE is the small punch test (accepted in 2002 as ASTM F 2183-02). The ASTM standard specifies the dimensions of the small punch specimen to be a round disk of 0.0200 +0.0002/-0.0003 in. in thickness and 0.250 +0.000/-0.005 in. in diameter. The authors of ASTM F 2183-02 use a lathe with a vacuum chuck and traditional machining techniques to machine specimens. The standard notes that alternative preparation methods may be used (e.g. microtoming), but that they have not yet been shown to provide equivalent results. These specimens are very difficult to produce due to the pliable nature of UHMWPE and the minute thickness tolerances on thickness (roughly the width of a typical human hair). The objective of this study was to develop and validate a more practical and affordable method for producing small punch samples of UHMWPE. Samples were prepared using a novel 'rotary cleaving' method, and then tested according to ASTM F 2183-02. The results were compared to the results of samples made using a lathe with a vacuum chuck and traditional machining techniques by the developers of ASTM F 2183-02.

Methods: A hand punch was used to prepare 0.25-inch diameter cylindrical sample plugs from the UHMPWE material to be tested. An inexpensive mini-precision lathe (with 0.001 in. increments) was then used to rotate these sample plugs at ~800 RPM. The samples were held in place with a speed chuck. If material geometry dictated the use of shorter sample plugs (less than ~0.3 in. in length), sample plugs were attached to the end of a steel rod with standard hot glue. A microtome blade was then vertically attached to the lathe's tool post via a custom-machined aluminum blade holder. The microtome blade was then advanced through the rotating sample plug in order to face off the sample. Subsequent cuts were then made at 0.0200-inch increments (multiple specimens can be harvested from one sample plug). A picture of the lathe setup can be seen in Figure 1. In order to validate the preparation method, 5 small punch specimens of compression molded GUR 1020 UHMWPE were prepared as outlined above. Specimen thickness and diameter for all samples were within the ASTM specifications. Measurement and testing of the specimens was performed as specified in ASTM F 2183-02.

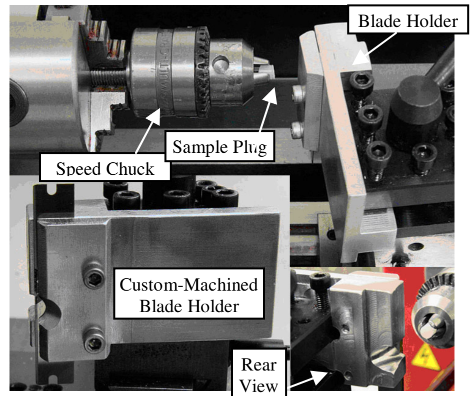

Figure 1. Specimen preparation setup

Results: Small punch test results of the compression molded GUR 1020 were compared with previously reported small punch data of the same material. The results are outlined in Figure 2.

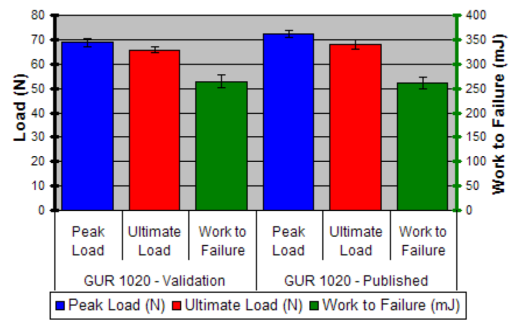

Figure 2. Method validation small punch results

The specimens prepared with the 'rotary-cleaving' method had similar peak load, ultimate load and work-to-failure values. The ultimate displacements differed slightly (4.87 +/- 0.10 mm vs. 3.78 +/- 0.14 mm for the published). These differences have been attributed to differences in the GUR 1020 manufacture and orientation.

Conclusions: The rotary-cleaving preparation method has demonstrated its utility in studies performed in our lab as a consistent, repeatable method. This novel 'rotary-cleaving' method for small punch specimen preparation is a practical alternative to using traditional machining techniques on an expensive vacuum lathe. A full inter-lab round-robin study to validate the rotary-cleaving preparation method in comparison to the vacuum lathe preparation method would fully validate the new process. To the authors' knowledge, there have not been any publications with small punch results reported according to ASTM F 2183-02 outside the labs of the developers of the standard. This is likely due to the high cost equipment and difficulty associated with producing samples within the tolerances specified. The method described here was developed for under $500 and has proven to be minimally time and resource intensive.