FEMORAL NECK AND ACETABULAR INSERT IMPINGEMENT WEAR TEST ON A HIP SIMULATOR

+*Schmidig, G (E-Howmedica Osteonics); *Dong, N (E-Howmedica Osteonics); *Wang, A (E-Howmedica Osteonics)
+HHowmedica Osteonics, Rutherford, NJ 07070. 201-507-7438, Fax: 201-507-7681, gschmidig@howost.com

Introduction
Impingement wear between femoral neck and the edge of the acetabular insert was found in 40% of the retrievals (1,2). The incidence was even higher in the dislocation cases (1). In order to better understand the wear mechanism under controlled in an in-vivo environment, the impingement simulator is required. Contrary to the ball and socket hip joint simulator, there was no hip impingement simulator reported to date. The purpose of this study was to develop and validate an impingement adapter to the existing MTS hip simulator and compare two different polyethylene insert materials under the simulated impingement condition.

Material and Methods
Two types of polyethylene treatments were utilized for this test. Both materials are manufactured and sold by Howmedica Osteonics for acetabular hip cup applications. The first set of inserts were machined from a UHMWPE extruded rod and packaged in a nitrogen environment. The package was then gamma irradiated at 3 mrad to sterilize the component. These components are referred to as nitrogen irradiated cups. The second set of cups were irradiated at 7.5 mrad to promote cross-linking followed by an annealing / stabilizing step at 135 +/- 5 degrees Celsius. The cup was then machined from this stabilized rod material and packaged in a nitrogen environment for sterilization at 3 mrad. These are referred to as highly cross-linked cups. Both sets of cups were 28 millimeter inner diameter and a 10 degree hood with a metal acetabular shell used to secure the polyethylene into fixture on the hip simulator.

An MTS hip simulator was set up to accept the impingement fixture. A normal walking cycle with a two-peak profile and a maximum load of 2.4 kNewtons was run at 1 hertz. The impingement fixture allowed the mounting of the cup in an anatomically correct position with axial load applied directly through the axis of the fixture that holds the shell. Impingement can occur freely without adding lateral force by adjusting the shell to an appropriate angle and locking it into position. An arm that is suspended off of the fixture and connects to the inner frame that holds the cup and shell, allows a force of 40 newtons to be applied. The impingement force Fi was derived from Fi=2Ff (friction force) under force and moment equilibrium conditions of femur with simplified assumptions. The friction force was generated between femoral head and polyethylene insert articulation surfaces and was directly related to the joint reaction force. Considering the impingement occurred shortly before toe-off in gait cycle as suggested by previous studies (2,3), the corresponding joint reaction force was 1/3 body weight according the published telemetric data (4). The test was conducted with alpha calf fraction serum (HyClone Labs, Logan, Utah) diluted to a physiologically relevant total protein concentration of ~20 grams per liter. A preservative of EDTA was added to control serum decomposition and precipitate formation.

The results were generated from a 0.5 million cycle (mc) test for the nitrogen irradiated inserts and 0.75 mc test for the highly cross-linked material. The initial results are a good indication of wear rates since we were testing the cups under normal hip simulator conditions and impinged conditions. The weight change was measured at 0.25 mc intervals and the wear rate was gained from linear regression curves of the data. Fluid absorption soak samples were used to minimize the effect of fluid uptake of the samples. The measurement of the impinged surface was analyzed for size and shape to describe the appearance of the surface.

Results and Discussion
The wear rate results for highly cross-linked material after normal non-impinged testing was 1.95 milligrams per million cycles (mg/mc). The highly cross-linked impinged material has an increase in wear and indicated 17.0 mg/mc weight loss. See Figure 1. The wear rate for the non-impinged normal hip simulator test is 9.9 mg/mc. The impinged material has an increase in weight loss with a reading of 57.3 mg/mc.

The highly cross-linked material starts out at a very low wear rate. The impingement does increase the wear as expected but the wear rate is still low when compared to a nitrogen irradiated material. Comparing the impingement data, the highly cross-linked material has a 70% decrease in wear.

The visual analysis (see Figure 2) of the impinged markings does indicate a large wear scar on both types of material. The appearance of the wear scars are similar in that they both have linear markings in the direction of contact with the femoral stem. The shape and size do correlate with a previously published paper (2) and indicate clinical relevance by duplicating the retrieved cup analysis. This hip simulator test can accurately test the impingement of acetabular cups on femoral necks.

Conclusion
Acetabular cup impingement on the femoral neck is seen in retrieved components. The impingement wear patterns from this study were consistent with the reported retrieval studies (1,2). The highly cross-linked polyethylene showed reduced wear for impingement and there was no fatigue failure observed. This study will provide the new testing method to optimize the implant design and material selection.

Figure 1 – Hip Simulator results of impingement test on highly cross-linked and nitrogen irradiated cups.

Figure 2 – Photograph of an acetabular cup after impingement test on a hip simulator. Impingement scar is on top.

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