ROLE OF CERAMIC/CERAMIC ARTICULATION IN THE ERA OF CROSSLINKED POLYETHYLENE

Wang, A. +Chopra, A.+ Schnädig, G. +Stryker Howmedica Osteonics, Mahwah, New Jersey

Introduction
Wear and wear debris induced osteolysis is a clinical concern in total hip arthroplasty. The industry has responded to the polyethylene wear problem by introducing highly crosslinked polyethylenes recently. Laboratory hip simulator testing has indicated that a significant wear reduction up to 90% can be achieved by elevated levels of crosslinking of the polyethylene under ideal conditions [1]. However, limitations of these crosslinked polyethylenes under non-ideal conditions such as against scratched femoral heads have also been reported [2]. These limitations are further explored in this investigation in a physiological hip joint simulator in which various 3rd-body wear environments are created in order to simulate the most common 3rd-body wear mechanisms in-vivo. In addition, a solution to the 3rd-body wear problem by using ceramic-on-ceramic articulations is proposed. These ceramic-on-ceramic bearing surfaces are subjected to the same 3rd-body wear challenges as the metal-on-polyethylene surfaces in the same hip simulator.

Materials and Methods
UHMWPE/CoCr: ram-extruded GUR1050 UHMWPE bars were irradiated by electron-beam at various doses ranging from 0 Mrads to 15 Mrads. Following irradiation, these bars were remelted at 150°C to eliminate residual free radicals. 32 mm diameter acetabular cups were machined from the bars. Depending on the dose of irradiation, various levels of crosslinking were achieved for the UHMWPE components. 32 mm CoCr were used in articulation against these polyethylene cups.

Ceramic/Ceramic: 32 mm diameter alumina ceramic cups and matching alumina femoral balls were evaluated as an articulating pair.

Hip Simulator Testing: a 12-station MTS hip simulator was used to evaluate the wear performance of both the UHMWPE/CoCr and alumina/alumina articulations. Diluted serum (50%water + 50% alpha-serum) was used as lubricant. To simulate 3rd-body wear damage, PMMA bone cement particles were mixed into the fluid in different test chambers at a concentration of 10 mg/ml. The bone cement particles were prepared by crushing pre-polymerized PMMA bone cement (Simplex, Howmedica Osteonics) at liquid nitrogen temperature and subsequently sieved through a 300μm mesh. Wear was measured by weighing the acetabular component every 500,000-cycle intervals. Total test durations were 2.5 million cycles. Wear rate was defined as volume loss per million cycles and was determined by linear regression. Students t-test was used to measure statistical significance (P<0.05).

Results and Discussion
UHMWPE/CoCr: The wear rates of the various crosslinked UHMWPE cups under both ideal (without 3rd-body particles) and 3rd-body conditions with bone cement particles are shown in Fig. 1. Under ideal conditions, the wear rate decreased exponentially with increasing the dose of radiation or crosslinking. For example, increasing the dose from 3 to 10 Mards led to a 90% reduction in the wear rate. Under the 3rd-body wear conditions, both the polyethylene cups exhibited significant increases in wear compared to the clean test. More importantly, all the benefits gains by crosslinking under the clean conditions were lost under the 3rd-body wear conditions. In fact, the wear rates under the 3rd-body conditions were actually less than that under clean conditions. In other words, the alumina/alumina articulation was extremely effective against 3rd-body wear damage. Since both non-crosslinked and crosslinked polyethylenes are susceptible to 3rd-body wear, the use of alumina on alumina articulation may provide a more effective solution to 3rd-body wear in-vivo.

Conclusions
Elevated levels of radiation crosslinking can significantly decrease the wear rate of UHMWPE under ideal conditions without 3rd-body particles. However, this benefit is significantly diminished under severe 3rd-body conditions. Therefore, the recent development in crosslinked UHMWPEs can only be considered as a partial solution to the clinical wear problem in THA. In contrast, the alumina/alumina bearings reduced the wear rates by as much as three orders of magnitude under both clean and 3rd-body conditions. Therefore, the use of the alumina/alumina articulation may provide a complete solution to the wear problem in THA.

References:

Fig. 1: Wear of UHMWPE cups against CoCr heads as a function of radiation dose under clean and 3rd-body conditions.

Fig. 2: Comparison of UHMWPE/CoCr and alumina/alumina wear under clean and 3rd-body conditions.

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