Effect of Vitamin E Enhanced Highly Cross-Linked Polyethylene on Wear Rate and Particle Debris in Anatomic Total Shoulder Arthroplasty: A Biomechanical Comparison to Ultrahigh-Molecular-Weight Polyethylene

Adam Khan, Andrew Jawa, Matthew J Smith, J Michael Wiater[1], Derek J Cuff[2], Anand M Murthi[3], Luke Stanford Austin
[1]Beaumont Health, [2]Suncoast Orthopaedic Surgery and Sports Medicine, [3]Medstar Union Memorial Hosp

INTRODUCTION: Particle-induced osteolysis resulting from polyethylene wear remains a source of implant failure in anatomic total shoulder designs. Modern polyethylene components are irradiated in an oxygen-free environment to induce polyethylene cross-linking, but an unfortunate byproduct of this process is free radical production. Melting or heat annealing is one method of reducing free radicals but can compromise the component's mechanical properties. The antioxidant, Vitamin E, has been introduced as an alternative adjuvant to neutralize free radicals. Specifically, in anatomic shoulder arthroplasty with a ceramic head component, the vitamin E-enhanced polyethylene showed improved wear compared to the conventional highly-cross linked polyethylene. This study aimed to assess the biomechanical wear properties and particle size characteristics of a novel vitamin E enhanced glenoid (VE-glenoid) compared to a conventional ultrahigh-molecular weight polyethylene glenoid (UHMW-glenoid).

METHODS: Biomechanical wear testing [**Figure 1**] was performed to compare the VE-glenoid to UHMW-glenoid with regard to polyethylene wear, pristine, and abrasive endurance, against a polished Cobalt Chromium Molybdenum (CoCrMo) alloy humeral head. Cumulative mass loss (mg) was recorded and wear rate calculated (mg/Mc). Under pristine wear conditions, particle analysis was performed and functional biologic activity (FBA) was calculated to estimate particle debris osteolytic potential. 95% confidence intervals for all testing conditions were calculated.

RESULTS: The average pristine wear rate was statistically significantly lower for the VE-glenoid compared to the UHMW-glenoid (0.81 +/- 0.64 mg/Mc vs. 7.00 +/- 0.45 mg/Mc) to a 95% confidence interval [**Figure 2**]. Under abrasive wear conditions, the VE-glenoid had a statistically significant lower average wear rate compared to the UHMW-glenoid (18.93 +/- 5.80 mg/Mc vs. 40.47 +/- 2.63 mg/Mc) to a 95% confidence interval. The VE-glenoid demonstrated a statistically significant improvement in FBA compared to the UHMW-glenoid (0.21 +/- 0.21 vs. 1.54 +/- 0.49) to a 95% confidence interval.

DISCUSSION AND CONCLUSION: A novel, anatomic vitamin E enhanced highly-crosslinked polyethylene glenoid component demonstrated significantly improved pristine and abrasive wear properties with lower osteolytic particle debris potential compared to a conventional ultrahigh-molecular weight polyethylene glenoid component. Vitamin E enhanced polyethylene shows early promise in shoulder arthroplasty components, long term clinical and radiographic investigation needs to be performed to verify these biomechanical wear properties translate to diminished long term wear and osteolysis.

Figure 1. Anatomic Glenoid Biomechanical Testing Setup. After a 5 year accelerated aging cycle, components were placed under compressive load, adduction-abduction, elevation, and translation to produce rolling, sliding and cross-shear. For abrasive testing, both glenoid and humeral components were roughed after aging cycle, prior to wear testing. Testing was performed at 37°± 2°C at 1 Hz for 5.0 Mc (Pristine) & 3.0 Mc (Abrasive) in bovine serum (total protein concentration of 62 g/L).

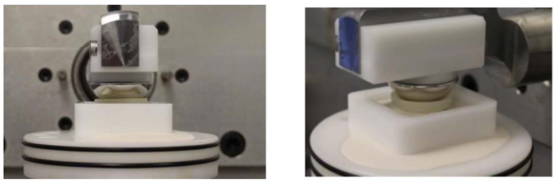

Figure 2. Anatomic Glenoid Representative samples after 5 million cycles. Both the A) UHMW-glenoid, and the B) VE-glenoid experienced burnishing and minor directional scratching with areas of deformation.