INTRODUCTION:

Previous studies have shown that acetabular inclination angle can affect the wear performance of implants [1,2]. Steep angles (>55°) reduce femoral head coverage thereby decreasing contact area and can subject the acetabular rim to excessive stresses [2]. These stresses have the potential to induce fracture to materials with suboptimal mechanical properties [3]. In the case of metal-metal implants it has been shown that at steep angles there is no bedding-in of the implants and run-away wear occurs [4,5].

The dual mobility bearing concept has over 30 years of clinical history; providing patients with improved joint stability [6]. The concept mates a metal femoral head with a polyethylene liner that is free to articulate inside a polished metal shell (fig 1). Previous work has shown acetabular wear can be minimized with this design [7], possibly through reduction of total amount of cross-shear motion that occurs on any one surface in a ball and socket joint. An additional potential benefit may exist through the maintenance of conforming contact and head coverage even under high inclination angle shell positioning. This should theoretically minimize edge related effects which could alter contact and stresses and ultimately wear performance.

The main objective of this study was to evaluate the influence of inclination angle on the wear performance of a dual mobility construct manufactured from sequentially crosslinked polyethylene (X3, Stryker Orthopaedics, Mahwah, NJ) compared to a metal-on-metal hip bearing and a conventional unipolar sequentially crosslinked hip bearing.

METHODS:

Two different inclination angles were used in this study (35 deg and 65 deg). Four sets of dual mobility implants (Restoration ADM, Stryker Orthopaedics, Mahwah, NJ), three sets of metal-on-metal (MoM) hip implants, and five sets of fixed (Trident®, Stryker Orthopaedics, Mahwah, NJ) hip implants (n=12) were evaluated for each inclination angle tested in this study. The dual mobility system was comprised of a metal femoral head (28mm nitrogen ion implanted (LF IT) CoCr) that is essentially an unconstrained or mobile acetabular insert with no outer locking mechanism. Fixed UHMWPE implants utilized a 40mm CoCr femoral head with modular liners retained in 54mm OD titanium metal shells (Trident®, Stryker Orthopaedics, Mahwah, NJ) [8]. The MoM components were fabricated from GUR 1020 UHMWPE that was sequentially crosslinked and annealed three times (X3 Stryker Orthopaedics, Mahwah, NJ) [9]. All polyethylene components were made of sequentially crosslinked polyethylene (X3, Stryker Orthopaedics, Mahwah, NJ) [8]. The MoM components were fabricated from high carbon cast CoCr as per ASTM F75 (no heat treatment). The MoM components utilized a 40mm femoral head size, inserts had a minimum thickness (under taper) of approximately 2.9mm, and the metal liners were retained in 54mm OD titanium Ti metal shells. The diametric tolerance clearance for the MoM articles was approximately 100 +/- 25µm, the roughness was less than 50µm and the sphericity was less than 15µm.

A hip joint simulator (MTS, Eden Prairie, MN) was used for testing with the cups positioned anatomically (superior) and oriented at either 35° or 65° of abduction. Testing was run at 1 Hz with cyclic Paull curve physiologic loading applied axially, at a maximum of 2450 N [9]. Component assemblies were lubricated using Alpha Calf Fraction serum (Hyclone Labs, Logan UT) diluted to 50% with a pH-balanced 20% MOPS solution of deionized water and EDTA (protein level = 20 g/l). The serum solution was replaced at 0.25 million cycle increments for the MoM components during the 65° angle study due to debris accumulation and darkening of the serum. All inserts (and femoral heads for MoM pairs) were weighed for gravimetric wear at every 0.5 million cycles. Dynamically loaded soak control specimens were used to correct for fluid absorption in UHMWPE samples with weight loss data converted to volumetric data (by material density). Statistical analysis was performed using the Student’s t-test (p<0.05). Testing ran for 2.5 million cycles per inclination angle.

RESULTS:

Volume loss results are shown in figure 1. Results for the 35 degrees of inclination angle condition show no statistical difference between any of the testing combinations with sequentially crosslinked polyethylene showing immeasurable wear. At this angle wear of the MoM devices was similar, although ion levels were not measured. Results for the 65 degree condition showed an increase for the fixed UHMWPE and MoM systems. The increase in fixed UHMWPE bearing wear is consistent with previous findings and still within noise level values [10]. The increase in MoM wear was substantial with both heads and cups showing scratches and abrasion damage related to edge contact. This damage was more pronounced on heads, likely due to the knife like edge that developed on MoM cups. There is a statistically significant wear rate reduction (p=0.0004 and p=0.0001) of over 94% for both the dual mobility and fixed bearing UHMWPE constructs when compared to MoM, respectively. When comparing wear rates of the dual mobility system to the standard unipolar fixed acetabular bearing, the dual mobility device exhibited an 85% (p=0.0077) reduction in wear rate.

DISCUSSION:

The results of this study support our hypothesis that acetabular wear at high angles can be diminished through design. This is likely due to maintenance of the nature of the primary inner bearing contact regardless of shell positioning. By decoupling the outer insert surface from the metal shell, the UHMWPE liner is allowed to optimize its position relative to both the head and shell based on friction at either surface as well transient contact conditions such as impingement. It is allowed to go where external conditions force it. Based on these results this dual mobility construct can be expected to outperform a conventional fixed construct and a metal-on-metal construct in terms of wear at high inclination angles. This system provides the stability of a large head with low wear characteristics and without any of the metal ion release concerns [11].

REFERENCES: