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Wear performance of cobalt chromium, ceramic, and oxidized zirconium on highly crosslinked polyethylene at mid-term follow-up

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ABSTRACT

Patients with THA using a ceramic head and using an OxZr head were each matched to patients with a CoCr head. Mean implantation time was 5 years. There was no difference in steady state wear rate between the ceramic (0.066 ± 0.050 mm/year) and CoCr match groups (0.052 ± 0.041 mm/year), or between the OxZr (0.022 ± 0.029 mm/year) and CoCr match groups (0.048 ± 0.071 mm/year). Follow-up into the second decade will be necessary before any changes in THA wear rate from using ceramic or OxZr bearings may be appreciated clinically with available imaging techniques.

1. Introduction

Total hip arthroplasty (THA) is a successful treatment option for patients with advanced hip arthritis. Engineering advances have enabled outstanding long-term survivorship, with polyethylene wear and associated osteolysis being greatly reduced with the advent of highly crosslinked polyethylene.[1] Now attention is turning to the other half of the bearing couple, with the goal of THA lasting for multiple decades.

Cobalt chromium (CoCr) femoral heads have long been the most frequent choice by surgeons for THA. In most cases it is less expensive than premium bearing options, offers modularity with low risk of implant fracture, and has good wear resistance when paired with highly crosslinked polyethylene. However, recent concerns surrounding trunnionosis at the head-stem junction have been raised.[2] The incidence of trunnionosis appears to be reduced or eliminated with the use of ceramic or oxidized zirconium (OxZr) heads.[3],[4]

Ceramic femoral heads have shown less friction, enhanced lubrication, and good resistance to abrasion, resulting in reduced conventional polyethylene wear rates compared to CoCr.[5],[6] However, ceramic femoral head fracture risk remains a concern.[7] OxZr was developed with the goals of reducing wear relative to CoCr heads and reducing the risk of fracture compared to ceramic heads. While wear simulator studies have demonstrated improved wear resistance with both ceramic and OxZr over CoCr, clinically, implant survivorship and patient outcomes have been no different.[8],[9]

It is important to critically evaluate new technology as it is introduced into orthopaedics, especially when new technology is offered at a cost premium.[10] There are many examples where new technology has been introduced, and has gone on to perform no better or even worse than existing products.[11] Therefore, the objective of this study is to examine, using radiostereometric analysis (RSA), the polyethylene wear rates of ceramic, OxZr, and CoCr on highly crosslinked polyethylene at mid-term follow-up. It was hypothesized that the two premium bearing materials would demonstrate lower wear than the CoCr bearing.

2. Materials and methods

We performed a retrospective review of our institutional arthroplasty database from 2004 to 2011. We identified all patients who underwent a primary total hip arthroplasty using highly cross-linked polyethylene. Patients that met the inclusion criteria were primary THA performed for osteoarthritis using a CoCr, OxZr, or ceramic femoral head on highly crosslinked polyethylene. Patients were excluded if they had undergone subsequent revision procedures or were outside 3–8 years post-operation. Patients were also excluded if they had cemented femoral implants. Our institutional research ethics boards approved the study. Patients were contacted by phone, and informed consent was obtained during their clinic visit.

The study cohort was narrowed into 4 groups: ceramic heads with a

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Table 1
Patient implant details and demographics.

Details	Ceramic (n = 20)	CoCr Match (n = 20)	p Value
Acetabular cup	Pinnacle (20)	Pinnacle (20)	1.000
Polyethylene liner	AltrX (17), Marathon (3)	AltrX (16), Marathon (4)	0.576
Femoral head diameter	28 mm (4), 32 mm (15), 36 mm (1)	32 mm (15), 36 mm (5)	< 0.001
Femoral stem	Summit (20)	Summit (20)	1.000
Age at surgery (years)	57.1 ± 6.1	57.2 ± 6.4	0.980
Sex	16 F, 4 M	16 F, 4 M	1.000
BMI (kg/m^2)	30.4 ± 6.4	31.0 ± 6.8	0.790
Implantation time (years)	5.1 ± 0.9	5.6 ± 0.8	0.076

Details	OxZr (n = 18)	CoCr Match (n = 18)	p Value
Acetabular cup	R3 (16), Reflection (2)	R3 (17), Reflection (1)	0.453
Polyethylene liner	R3 XLPE (16), Reflection XLPE (2)	R3 XLPE (17), Reflection XLPE (1)	0.453
Femoral head diameter	28 mm (1), 32 mm (10), 36 mm (7)	32 mm (15), 36 mm (3)	0.055
Femoral stem	Synergy (17), Anthology (1)	Synergy (13), SMF (4), CPCS (1)	0.035
Age at surgery (years)	59.9 ± 5.6	60.1 ± 6.0	0.910
Sex	8 F, 10 M	8 F, 10 M	1.000
BMI (kg/m^2)	31.0 ± 5.6	35.2 ± 8.5	0.057
Implantation time (years)	5.2 ± 0.9	5.4 ± 0.8	0.606

matched group of CoCr heads (n = 20 per group), and OxZr heads with a matched group of CoCr heads (n = 18 per group). Matching was based on age, gender, and body mass index (BMI). The ceramic and matched CoCr group used Depuy (Warsaw, IN) implants (Table 1), including both Marathon and AltrX highly crosslinked polyethylene. Marathon polyethylene was introduced in 1998 and is made from extruded rod GUR 1050 polyethylene, gamma irradiated to 50 kGy, followed by melting and annealing, with gas plasma sterilization. AltrX polyethylene was introduced in 2007 and is made from extruded rod GUR 1020 polyethylene, gamma irradiated to 75 kGy, followed by melting and annealing, with gas plasma sterilization. The OxZr and matched CoCr group used Smith & Nephew (Memphis, TN) implants with XLPE highly crosslinked polyethylene. XLPE was introduced in 2001 and is made from extruded rod GUR 1050 polyethylene, gamma irradiated to 100 kGy, remelted, and sterilized with ethylene oxide. Patient demographics for all groups are listed in Table 1.

Patients underwent a standard supine radiostereometric analysis (RSA) exam of the hip. In conventional RSA, prospective exams are acquired over multiple time points, defining the initial bedding in period due to creep and subsequent steady state wear rate.[12] RSA wear analysis can also be performed in a retrospective manner using the center index method.[13] With this method, the relative location in three-dimensional space of the femoral head to the acetabular cup is measured in the present-day exam. The immediate post-operation position of the head to the cup is assumed to be a central point defined by the circumference of the acetabular cup. The relative difference between these two positions is calculated as wear. Although this technique has been demonstrated to be accurate, it includes both creep (from the bedding-in period) as well as wear, thereby overestimating the true wear rate.

Therefore, to account for the bedding-in period, we utilized the Martell method to measure the relative position of the head versus the cup from anterior-posterior and lateral radiographs of each patient acquired at 1 or 2 years post-operation.[14] The three-dimensional distance between the head and cup at 1 or 2 years was subtracted from the distance between the head and cup at the latest follow up, yielding the true head penetration due to wear. This value was divided by the implantation time less 1 or 2 years (as appropriate), to provide the steady state wear rate. In some cases 1 or 2 year radiographs were unavailable, so 6-week radiographs were used instead, and the total implantation time was used to determine the wear rate. In these instances, both creep and wear are part of the wear rate. The 6-week radiographs were required for 3 ceramic and 1 matched CoCr case, and for 2 cases in the OxZr and 1 matched CoCr case.

With low wear rates using highly crosslinked polyethylene and the uncertainty of the wear measurements, negative wear rates can occur, and can be addressed in multiple ways.[15] These values can be left in the calculation of the average wear rates, but tend to artificially decrease the average as they cancel out positive wear. Alternatively, these values can be excluded, but tend to artificially increase the average wear rate as only high wearing values will be included. Finally, negative values can be treated as equivalent to no wear and given a value of 0, which is likely most representative of the true case. All three methods of calculation were performed and included for completeness.

Patient-reported outcome measures were recorded pre-operatively and at the time of the follow-up imaging. Outcome scores collected included the Western Ontario and McMaster Osteoarthritis Index (WOMAC), Harris Hip Score (HHS), and the Short Form Health Index (SF-12).

Descriptive statistics (means and standard deviations) were calculated for patient demographics, wear rates, and outcomes scores. The D'Agostino and Pearson normality test was applied to assess the distribution of the data. Subsequently, either a *t*-test or a Mann-Whitney *U* test was used to compare the groups, depending on whether the data was normally distributed or not, respectively. For ratios of specific implant variables between groups, a chi square test was used to calculate the difference in distribution. All statistics were completed using Prism 7 (GraphPad Software Inc., La Jolla, CA).

3. Results

The magnitude of steady state wear rates varied by method of calculation (Table 2). There was no significant difference in wear rates between ceramic heads and the matching CoCr heads, or between OxZr heads and the matching CoCr heads, regardless of calculation method. Using the negatives set to 0 calculation method, there was no significant difference in wear rates between the CoCr ceramic match and OxZr match groups (mean difference = 0.004 mm/year, p = 0.316). However, using the negatives set to 0 calculation method, the OxZr group had a significantly lower wear rate than the ceramic group (mean difference = 0.044 mm/year, p = 0.002).

The ceramic-matched CoCr head group demonstrated a significantly greater improvement in the SF12 mental component score (Table 3) compared to the ceramic group (p = 0.032, mean difference = 9.1). However, the ceramic group demonstrated a significantly greater improvement in the SF12 physical component score compared to the matched CoCr group (p = 0.002, mean difference = 12.8). There were no differences in the OxZr and matched CoCr groups for either SF12 score. There was no difference in any groups for WOMAC or Harris Hip

Table 2
Wear rates by group.

Measurement (mm/year)	Ceramic	CoCr Match	p Value
All Values	0.066 ± 0.050	0.047 ± 0.049	0.478
Negatives Excluded	0.066 ± 0.050	0.069 ± 0.032	0.458
Negatives Set to 0	0.066 ± 0.050	0.052 ± 0.041	0.477

Measurement (mm/year)	OxZr	CoCr Match	p Value
All Values	−0.007 ± 0.062	0.011 ± 0.108	0.743
Negatives Excluded	0.050 ± 0.069	0.109 ± 0.069	0.050
Negatives Set to 0	0.022 ± 0.029	0.048 ± 0.071	0.516