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THA Retrievals: The Need to Mark the Anatomic Orientation of the Femoral Head

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ABSTRACT

The hypothesis of this study was that the rotational orientation of femoral head damage would greatly affect the volumetric wear rate of the opposing polyethylene (PE) liner. Damage on twenty retrieved cobalt–chromium femoral heads was simulated in a validated damage-feature-based finite element model. For each individual retrieval, the anatomic orientation of the femoral head about the femoral neck axis was systematically varied, in 30° increments. The PE wear rate differential between the maximum- versus minimum-wear orientations was often sizable, as high as 7-fold. Knowing the correct femoral head anatomic orientation is therefore important when analyzing the effects of femoral head damage on PE liner wear. Surgeons retrieving modular femoral heads should routinely mark the anatomic orientation of those components.

Damage to the femoral head of a total hip arthroplasty (THA) can cause accelerated wear of the opposing polyethylene (PE) acetabular liner, which can then result in osteolysis, aseptic loosening, and THA failure. In addition to the damage severity per se, the location of a roughened site on the femoral head affects the wear rate of the opposing PE liner [1]. The rotational orientation of damage on the femoral head, based on the anatomic orientation of the femoral head about the femoral neck axis, would therefore be expected to have an effect on liner wear rate.

For studies involving retrieved modular femoral heads, specification of an anatomic orientation of the femoral head or its damage [2,3], illustration of an anatomic orientation marking on a head [4,5], or a statement that the anatomic orientation was marked [6] is rare. Without knowledge of femoral head anatomic orientation, documentation of femoral head damage is incomplete.

Knowledge of the anatomic orientation of retrieved femoral heads, and of the resultant rotational orientation of femoral head damage, would enhance subsequent retrieval analysis. For example, this knowledge would appear to be essential for accurate calculation of liner wear. Recent advances in damage-feature-based finite element (FE) modeling allow for quick and efficient evaluation of patient-specific femoral head damage [7,8]. The hypothesis of this study was therefore that rotational orientation of damage on retrieved femoral heads has a marked influence on the volumetric wear rate of the opposing polyethylene liner, as predicted by finite element analysis.

Materials and Methods

Twenty retrieved cobalt–chromium modular femoral heads (Table 1, Fig. 1) that had articulated against a PE liner, had a variety of damage levels, and did not have an indication of anatomic orientation were analyzed. Retrieval components and clinical data were collected and analyzed with IRB approval. Damage was localized and quantified on these heads, using a combination of diffused-light photography [9], image analysis [7], and optical profilometry. Canny edge detection was performed on the photographs to detect regions of damage. A Hough transform was used to discretize scratches into straight-line segments. Regions showing scrape damage were segmented into quadrahedral-shaped patches. Damage severity was determined by scratch lip heights and scrape average roughness (R_a) values, which were measured via optical profilometry scans of the damaged regions.

These damage data were then used to simulate femoral head damage in a damage-feature-based FE wear model [8]. Femoral head scratches and scrapes, along with their corresponding lip heights and R_a values,

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Table 1
Retrieved Femoral Heads Studied. All Heads Were Modular Cobalt–Chromium and Articulated Against Polyethylene.

Femoral Head Number	Time to Retrieval (Years)	Reason(s) for Retrieval
1	6.2	Dislocation
2	10.5	Aseptic loosening
3	0.8	Dislocation
4	5.1	Septic loosening
5	0.4	Dislocation
6	13.5	Aseptic loosening
7	0.2	Dislocation
8	14.8	Wear
9	3.0	Dislocation
10	9.8	Dislocation
11	4.4	Chronic dislocation and aseptic loosening
12	5.6	Recurrent subluxation
13	16.0	Wear
14	0.4	Dislocation
15	5.4	Dislocation
16	7.4	Dislocation
17	1.5	Dislocation
18	18.9	Dislocation
19	0.2	Dislocation
20	8.9	Wear

were modeled at their respective damage locations. A finite element model for PE liner wear, experimentally validated for conventional polyethylene [8,10,11], was then implemented in ABAQUS v6.9.1, using the adaptive meshing capabilities of the UMESHMOTION subroutine. PE liner wear was computed using the Archard wear formula [12], which calculates the spatial distribution of wear depth as a function of local contact pressure, sliding distance, and a wear coefficient based on the tribological properties of the surfaces in contact. When an area of the acetabular liner was overpassed by a femoral head damage feature, the wear coefficient was elevated, based on the damage feature severity and on the angle between the orientation of the damage feature and its direction of motion. The anatomic orientation of the femoral head about the femoral neck axis was systematically varied, in 30° increments. Wear simulations were run to one million standard gait cycles. All femoral head diameters were normalized to 28-mm diameter for comparison to a simulation with an undamaged 28-mm femoral head.

Polyethylene wear acceleration, defined as the wear volume caused by a damaged head relative to that caused by an undamaged head, was computed for each simulation. For each femoral head, wear rate differential was defined as the maximum wear value divided by the minimum wear value. Spearman's rank correlation coefficient (ρ) was calculated between the wear rate differential and the maximum wear acceleration.

Results

Depending on the damage on and the posited anatomic orientation of the femoral head, PE liner volumetric wear acceleration ranged

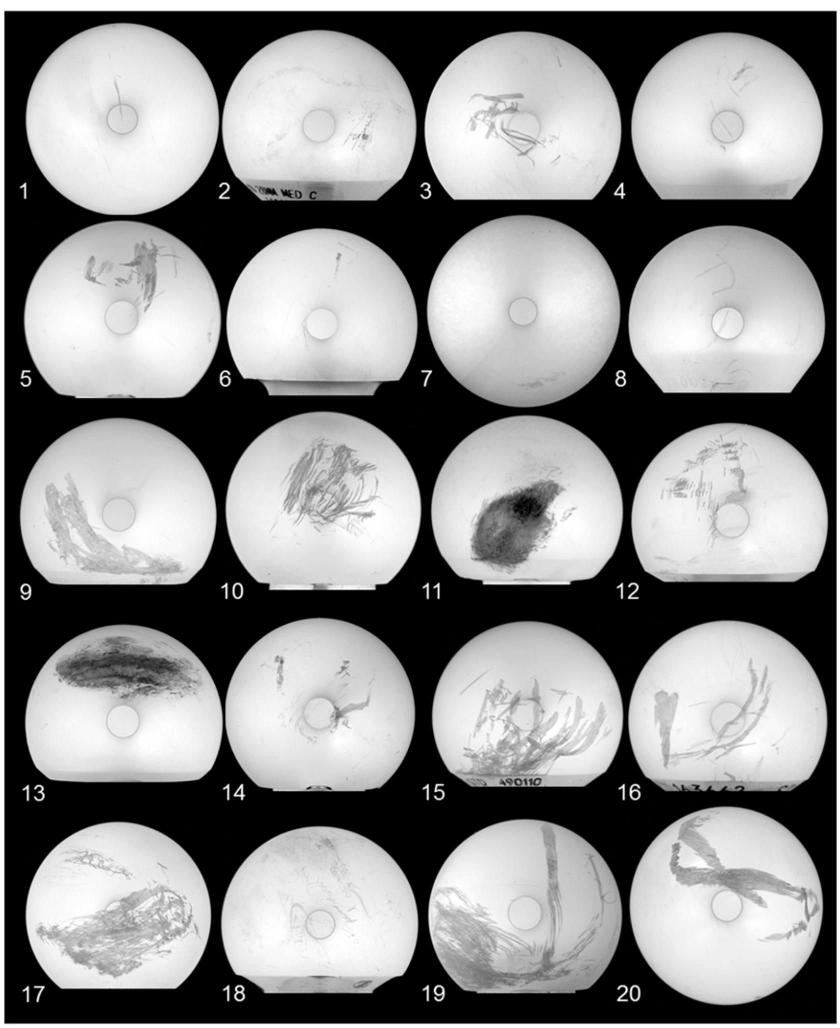

Fig. 1. Retrieved femoral heads analyzed, shown from the view displaying the highest severity of visually-observed damage. This was the polar direction for heads #1, #7, and #20. The photographs for heads #1, 3–10, 12, and 14–20 have appeared in previous publications [7–9,22,23].