Estimation of In Vivo Positioning of Femoral Head Dislocation Retrievals for Case-Specific Retrieval Wear Simulations

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Introduction: Damage to a total hip arthroplasty (THA) femoral head can cause greatly accelerated wear. Dislocations in particular have been shown to cause severe scrape damage [1]. In addition to the damage severity per se, location of a roughened site on the femoral head affects the wear rate of the opposing liner [2]. In the case of retrieval components, the circumferential orientation of a damaged femoral head about the femoral neck axis affects the liner wear rate [3]. Retrieval studies only rarely provide any indication of the anatomic orientation of the femoral head or its damage. However, in the case of dislocations, the scrape damage due to acetabular shell contact tends to occur at characteristic locations. The hypothesis of this study was that characteristic dislocation damage locations could be used to estimate the otherwise unknown in vivo orientation of retrieval femoral heads. The knowledge of this orientation could then be used to develop case-specific finite element (FE) wear models to determine the polyethylene (PE) wear acceleration potential of these damage features. The purpose of this study was to compare the known orientation of retrievals to estimated orientations and their respective wear potentials.

Methods: Five CoCr femoral heads that had undergone dislocation(s), and for which the head-on-trunnion orientation was known, were selected from our laboratory’s retrieval collection. A multi-stage, multi-scale imaging procedure consisting of diffused-light photography (Figure 1) and 3-D optical profilometry was used to globally locate and quantify femoral head damage on those retrievals. These data were then used to represent femoral head damage in a damage-feature-based FE model [4]. When an area of the acetabular cup was overpassed by an area of femoral damage, the PE wear factor was elevated based on the damage severity and relative motion directionality.
Femoral head damage locations from previous FE simulations of squat, stoop, sit-to-stand (normal), and sit-to-stand (low) challenges [5] were used to estimate the in vivo orientation of each retrieval (Figure 2). The damage centroid of each retrieval was identified and the orientation of the retrieval femoral head on the trunnion was then perturbed about the trunnion axis until the distance between its damage centroid and the FE model’s damage centroid was minimized. FE models of PE wear were run for the known anatomic orientation, and for each of the estimations from the four dislocation challenge models. The positioning error was measured by the difference between the actual anatomic orientation of the retrieval and the estimation from the FE models.

**Results:** The stoop and squat challenges best predicted the component position in all cases except retrieval B (Figure 3a). The FE wear simulations for the models with the lowest positioning error showed
PE wear volume errors of 11\% for sample A and 1\% for samples B-E, relative to the actual anatomic wear rate (Figure 3b).

**Discussion:** This position estimation method predicted the anatomic orientation of the dislocation retrievals to within 10° for squat and stoop challenges. This level of agreement between the actual retrieval location and predicted location was very encouraging, and validates this orientation estimation method’s ability to realistically replicate in vivo orientations. This level of agreement was not observed with retrieval B, however. While most dislocation retrieval damage was isolated to a single area, retrieval B displayed damage at multiple locations (Figure 1), as could happen following multiple dislocation and/or subluxation events. The hip for retrieval B experienced recurrent subluxation in addition to two dislocations.

Dislocations are complex events. While FE models of various simplified dislocation-prone challenges provided close orientation estimations in most cases, knowledge of the actual anatomic orientation of the femoral head is still the gold standard in connecting component damage to pathological processes such as bearing surface wear, dislocation, subluxation, and taper-trunnion damage. Retrieval program coordinators and participating surgeons need to give enhanced attention to the issue of component anatomic orientation [3]. This orientation estimation technique can provide a reasonable estimation for dislocation cases when no other information is known. In future cases where dislocation direction is known, this model could be further improved to determine if there is any link between dislocation direction and wear potential.

**Significance:** Dislocation retrieval femoral head positions can be estimated using commonly occurring damage locations. This provides information on femoral head orientation that is often lacking in retrieval studies.

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