Introduction: Surface damage on ultra high molecular weight polyethylene (UHMWPE) acetabular components has been attributed to high contact stresses, and has been found to be increasingly evident in thinner acetabular components. Historically, it has been recommended that a minimum polyethylene thickness in the range of 4–6 mm be maintained in order to minimize the potential risk of such damage. It is also recognized that larger diameter femoral heads offer the advantages of an increased range of motion due to an increased head/neck ratio, and increased stability as a result of the increased translation necessary for femoral head dislocation. As a result, larger head diameters can effectively reduce dislocation, which is a major complication after total hip arthroplasty. An increase in femoral head diameter can be obtained by a reduction in UHMWPE thickness. Geometric parameters that influence peak contact stresses in fully supported, UHMWPE acetabular components include the femoral head diameter, acetabular insert thickness, and the degree of bearing surface conformity. A parametric investigation was performed to evaluate the peak UHMWPE contact stress that develops within a family of commercially available, UHMWPE acetabular insert designs which accommodate a wide range of femoral head sizes and UHMWPE thicknesses. The maximum contact stress that develops, as influenced by the geometric parameters identified above, was compared to the contact stress that develops in a smaller sized, clinically successful device of 7.9 mm UHMWPE thickness. The objective of this study is to evaluate the historical UHMWPE minimum thickness recommendations through the prism of currently available, fully supported, larger femoral head diameter, acetabular insert designs. Finite element analysis techniques were utilized for the purposes of this evaluation.

Materials and Methods: A series of 15 finite element models consisting of a CoCr femoral head, an UHMWPE acetabular insert, and a Ti-6Al-4V acetabular shell (Trident® & LFIT® Anatomic X3™ polyethylene acetabular systems, Stryker Orthopaedics, Mahwah, NJ) was generated within ANSYS v10 (ANSYS, Inc., Canonsburg, PA). A flexible material layer supports the acetabular shell, providing a more clinically relevant boundary condition. Due to symmetry in geometry, load, and boundary conditions, a 180° FE model was developed. A 50° acetabular cup inclination angle was utilized for this investigation. A wide range of UHMWPE acetabular inserts were analyzed, ranging in thickness from 3.8 to 14.7 mm, and ranging from 22 to 44 mm in femoral head diameter. A peak compressive force of 2,450 N (550 lbs) was applied to the finite element model in UHMWPE thickness. Geometric parameters that influence peak contact stresses in fully supported, UHMWPE acetabular components include the femoral head diameter, acetabular insert thickness, and the degree of bearing surface conformity. A parametric investigation was performed to evaluate the peak UHMWPE contact stress that develops within a family of commercially available, UHMWPE acetabular insert designs which accommodate a wide range of femoral head sizes and UHMWPE thicknesses. The maximum contact stress that develops, as influenced by the geometric parameters identified above, was compared to the contact stress that develops in a smaller sized, clinically successful device of 7.9 mm UHMWPE thickness. The objective of this study is to evaluate the historical UHMWPE minimum thickness recommendations through the prism of currently available, fully supported, larger femoral head diameter, acetabular insert designs. Finite element analysis techniques were utilized for the purposes of this evaluation.

Discussion: Finite element analysis techniques were used to evaluate the effect of thickness on the contact stress of acetabular inserts that utilize fully supported, UHMWPE as the polyethylene material. This study compares the acetabular insert contact stresses for a wide range of commercially available device sizes within a specific design family. The analysis results confirm 2 significant design trends. The maximum acetabular insert contact stress decreases as insert thickness increases, while the maximum acetabular insert contact stress decreases as the femoral head diameter increases. This study presents the combined, interrelationship between these two trends. The FEA results indicate that fully supported, large diameter, acetabular inserts of thicknesses as low as 3.8 mm generate contact stresses that are either substantially equivalent to or less than that of a clinically successful acetabular device (i.e., the A22 size insert) of 7.8 mm thickness. A physical test was performed to validate the ability of a fully supported, 2.2 mm thick UHMWPE prototype to sustain high, cyclic loading. There was no visible evidence of significant deformation or degradation in any of the four samples tested. This study demonstrates that an acetabular insert thickness threshold as low as 3.8 mm can be considered for specific fully supported, UHMWPE acetabular inserts. The expected resulting benefit is an enhanced patient outcome by means of increased range of motion and a reduction in dislocation rates.