

Ceramic Total Hip Liner Fracture Modeling in Abaqus using co-Simulation and Extended Finite Element Modeling

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Abstract: *Due to concerns over particle generation in conventional metal-on-polyethylene hip bearings used in total hip arthroplasty (THA), interest in advanced low-wear bearing alternatives such as ceramic-on-ceramic (CoC) couples has reemerged. While ceramics demonstrate excellent compressive strength, the brittle nature of the material reduces tensile strength, possibly leading to catastrophic fracture when loads exceed material limits. Impingement between the femoral neck and acetabular liner gives rise to areas of extreme transient stress concentration, which have been clinically linked to fracture. This work presents methodology for the investigation of 3D ceramic fracture initiation/propagation using Abaqus' co-simulation and extended finite element modeling (XFEM) capability. An anatomically realistic and physically validated FE model of a THA-implanted hip joint was developed, which employs physiologically accurate hip joint soft tissue capsule utilizing Abaqus' built-in Holzapfel-Gasser-Ogden Anisotropic Hyperelastic material model. Given the complex contact and non-linear material behavior of the capsule during large rotational displacement of the implant, the use of Abaqus' co-simulation allows for seamless Abaqus/Explicit analysis of soft-tissue and Abaqus/Standard analysis of hardware interaction and fracture mechanics. The use of XFEM has proven to be a valuable technique to investigate crack initiation and propagation, phenomena which have been tedious or impossible to adequately explore using conventional finite element fracture mechanics. The utilization of these Abaqus capabilities allows for a quantitative assessment of surgical- and patient-specific factors which predispose ceramic hip liners for catastrophic failure.*

Keywords: *Orthopaedics, Fracture, Crack Propagation*

Introduction

Advances in implant material design as well as surgical technique and instrumentation have made total hip arthroplasty (THA) one of the most successful interventions in medicine today (D'Antonio, 2002). Total hip replacement provides rapid relief of pain and restoration of mobility for patients afflicted with lower-extremity pathologies including osteoarthritis, traumatic fracture, or other insults to the hip joint. It is estimated that approximately one million total hip replacement surgeries are conducted each year (Isaac, 2006), with over 250,000 cases performed