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SUBJECT SPECIFIC ANALYSIS OF CHONDROLABRAL STRESSES IN A PATIENT WITH CAM FEMOROACETABULAR IMPINGEMENT

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Introduction

Osteoarthritis (OA) is a relatively common orthopedic ailment that affects nearly 14% of persons aged 25 years and older, which increases to 35% of those aged 65 and older in the United States [1]. Often, OA causes pain, debilitation, and loss of joint function. For patients with mild hip OA, treatment is focused on preserving the native hip. In more advanced cases, prosthetic replacement of the joint is necessary to alleviate symptoms and improve function [2]. Cam femoroacetabular impingement (FAI) is a known cause of hip OA [3,4]. Morphologically, patients with cam FAI present with an aspherical femoral head (Fig. 1), which is thought to disrupt normal articulation of the hip, leading to pain, loss of range of motion, and damage to the cartilage and acetabular labrum. However, the pathomechanics of cam FAI are poorly understood, as cartilage and labral mechanics cannot be measured directly in-vivo. In this study, we developed a finite element (FE) model of a patient with cam FAI to estimate chondrolabral (cartilage and labral) stresses.

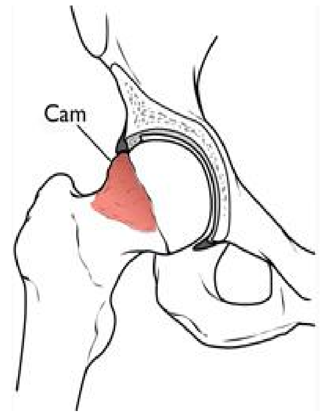

Figure 1: Schematic showing bony growth that characterizes cam FAI [1].

Methods

The FE model was developed from computed tomography (CT) arthrography images, which visualized bone, cartilage, and labrum of a subject with cam FAI. Utilizing methodology validated by Anderson *et al.*, hexahedral meshes were generated of the acetabular and femoral cartilage as well as the labrum [5-7]. Shell elements were used to represent cortical bone. The bone surfaces and cartilage volumes were imported to PreView (v1.18.1, University of Utah) software in the neutral position to apply material properties, boundary conditions (e.g. kinematic position of the hip), and loading condition (e.g. force across the hip) during simulated activities of daily living. The acetabular cartilage and labrum FE meshes were bisected to separate acetabular cartilage from the labrum, as these structures have distinct material properties. The applied material properties were consistent with previous FE modeling studies of the hip [5,6]. The neutral model was modified to represent six different activities of daily living by applying angle and transition displacements to the femur, in accordance with each activity. These modifications are enumerated in a study compiled by Bergmann *et al.*, as representative data sets of the "kinematics of daily living" from patients with hip implants containing force sensors [8].

Results

The FE results reporting stress at the acetabular cartilage and labrum were visualized in PostView (v1.8.3, University of Utah) Heel-strike during walking resulted in concentrated stresses, while stresses were more diffuse during toe-off at walking (Fig. 2).

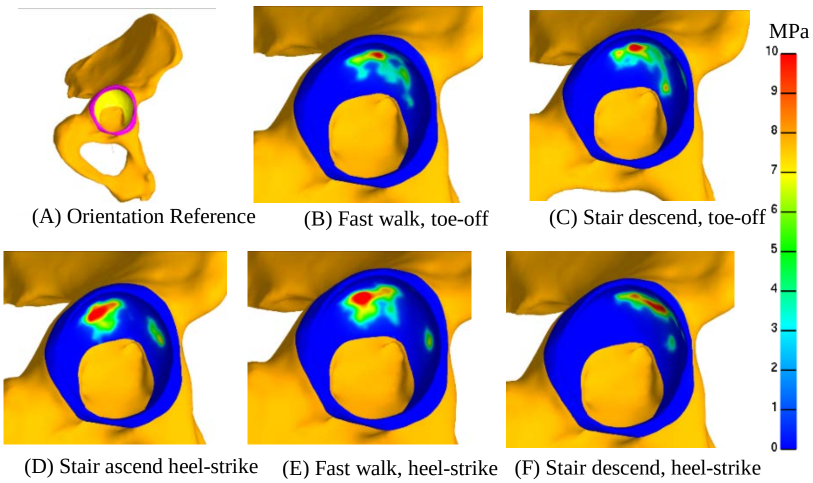

Figure 2: Contact stress maps from a variety of daily living activities. *Note, “Stair ascent, toe off” not included due to irreparable mechanical collisions in the model assembly phase.

When averaged across each region, it was determined that stresses were highest in the superior acetabulum (Fig. 3). Stress values in other locations varied substantially across the activities. In general, stresses were highest during fast walking in the superior acetabulum, with very little stress in the surrounding regions. During stair descent, stresses were more evenly distributed, but were still located in the superior cartilage. In both the heel-strike and toe-off events of stair descent, the anterior cartilage and labrum also experienced considerable stress. For the stair ascent activity, stresses were concentrated in the superior cartilage, with minor stresses noted in the anterior cartilage. Other stresses in this activity were minimal. During all activities, stresses in the posterior region were much less than the superior region.

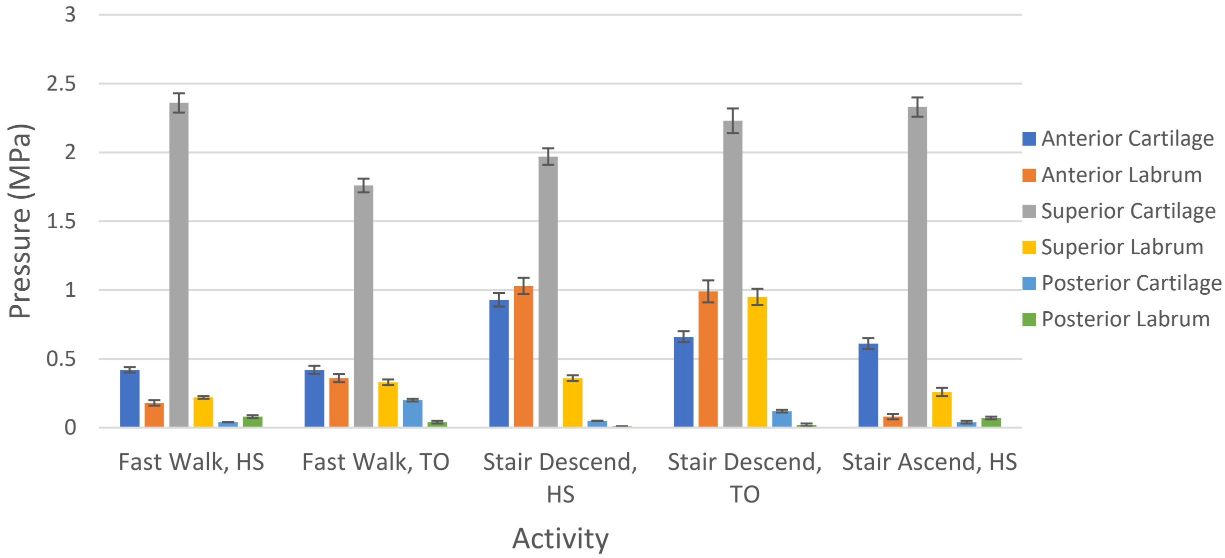

Figure 3: Average contact stress per cartilage or labrum section, grouped by activity. HS, heel strike; TO, toe off, data presented as mean (95% confidence interval) in MPa. Note that stair ascend toe-off is not included.

Discussion

While there were differences in the distribution of loading within the joint due to the different activities, loading was heavily biased towards the superior cartilage region, where damage most often is observed in FAI patients (Fig. 2, Fig. 3). During stair descent the anterior cartilage and labrum demonstrated substantial stresses (Fig. 2, Fig. 3). Posterior loading was almost nonexistent in all activities attempted (Fig. 3). Ideally, once more models are completed, a body of knowledge can be generated to educate physicians, and assist them in making more informed decisions during resection surgeries, and other medical interventions used to treat cam FAI. Additional sister projects involving shape modeling, to better quantify the average shape, thickness, and density of cam lesion, are underway. This may lead to a body of research that may allow greater confidence in diagnoses.

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