Investigating osteoarthritis in the human hip using three-dimensional finite element models.

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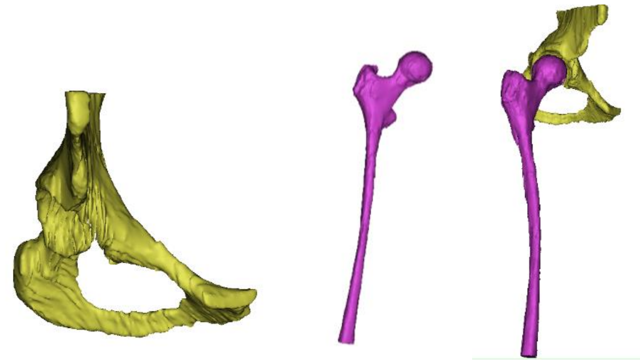
Summary
This project uses complex three-dimensional finite element models to investigate the impacts of osteoarthritic damage regarding loading patterns and stress points in the human hip. This study could show the isolation of the structure and exclusion of other factors that may influence biomechanics of the hip. This will ascertain the extent of the influence the osteoarthritic damage itself has upon locomotion and loading of the hip.

Introduction
Osteoarthritis (OA) is a term for the degeneration of cartilage present in joints in the body, causing stiffness and pain from bone contacting bone and the myriad of issues stemming from this contact[1]. Specifically, hip osteoarthritis refers to the damage of the articular cartilage found on the head of the femur and surface of the acetabulum, and the discomfort and impaired movement associated with these two bone surfaces rubbing together. Current literature suggests that this can cause a shift in loading of the hip, theorised to be the patient altering gait mechanics, therefore loading patterns, to alleviate the symptoms of osteoarthritis [2,3]. It could be the anatomy of the damaged cartilage influences loading patterns, even when isolated from patient attempts to alter the load. Through the creation of a complex three-dimensional finite element healthy hip model, it is possible to simulate differing loads placed upon the joint and the articular cartilage, and evaluate where specifically points of stress on the structure are located in a healthy human hip. An OA version of the complex three-dimensional human hip model was also created to undergo the same experimental process, yielding comparable data on stress points in the structure. Using this model, behavioral elements have been removed from the study, allowing an evaluation of the extent the articular cartilage itself plays a role.

Methods
MRI scans of a healthy human hip were taken from a 20-year-old female. The subject had no medical issues relating to the hip or spine [4]. This MRI data-set was then put into Mimics Research 21.0 software where the pelvis (including: partial ilium, complete ischium, partial pubis, and complete acetabulum with articular surface, acetabular fossa and acetabular labrum), femur (including: complete proximal end with femoral head articular cartilage), and ligaments (iliofemoral, the pubofemoral and ischiofemoral) were segmented and converted into a three-dimensional model (Figure 1). Subsequently, the model was copied; the articular cartilage and femur head re-segmented to represent an OA hip. This involved the flattening of the superior side of the femur head and thinning of the cartilage [5]. Changes were made in line with clinical presentations of hip OA across multiple MRI scans found in the literature. These models were imported to finite element analysis software, ABAQUS. They were tested with varying loading and boundary conditions to analyse sensitivities. Material properties and loading values of differing tissue was taken from the literature.



(a) **(b)** **(c)**

Figure 1: Rough draft models for cancellous femur (a), cancellous pelvis (b) and both combined (c). Yet to model cortical bone, cartilage and ligaments.

Results and Discussion
The finite elements analysis showed a shift in loading patterns, even when separated from a human subject and their gait mechanics, due to the abnormal shape of the hip joint created by OA, in turn causing to the OA model to possess differing stress points to the healthy model. The data provides evidence of the significant role the articular cartilage alone plays in loading patterns, helping to further our understanding of OA and its relationship with biomechanics.
The developed finite element model could be used as an asset for further research of the human hip including: investigating biomechanics of different clinical presentations of osteoarthritis, long term effect of altered gait mechanics on the hip, investigating new methods of total hip arthroplasty.

Conclusions
Articular cartilage and femur head structure resulting from OA changes the loading patterns of the human hip during gait, independent of loading patterns caused by patients altering gait mechanics themselves.

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