Population-Based Shape and Biomechanical Analysis of Hip Pathoanatomy

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NIH R01 EB016701
Scientific Goals

Aim 1: Develop and modify tools to identify shape differences between groups, to discover shape variations associated with clinically relevant parameters related to musculoskeletal disorders. Integrate ShapeWorks with FEBio to enable flexible and robust analyses of shape and function.

Aim 2: Using SSM tools from Aim 1, quantify the variation in femoral head anatomy and acetabular rim coverage among normal hips and hips with cam/pincer/mixed type FAI.

Aim 3: Use the integrated software application from Aim 1 to examine the correspondence between shape and mechanics in a population of patients with hip dysplasia.
Research Team

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Femoroacetabular Impingement (FAI)

Structural hip deformities thought to reduce clearance

- "Cam" deformity
- Femoral Head Asphericity
- "Pincer" deformity
- Acetabular Over-coverage
By quantifying the spectrum of patient-specific pathomorphology and its influence on the mechanics of chondrolabral tissue, we can identify its relationship to early OA, and ultimately improve diagnosis and treatment strategies.
Patient-Specific Finite Element Modeling

Normal, Dysplastic, Retroverted, FAI

CT Arthrogram → Segmentation → 3D Reconstructions → Mesh Discretization → Subject-specific FEA Model → Contact stress

Material Model

Boundary and Loading Conditions

Contact Stress in Normal Subjects
- Walking Foot Strike
- Ascending Stairs Foot Strike
- Descending Stairs Foot Strike

0 MPa → 8 MPa

Contact area % labrum load
Volumetric Imaging

- Pelvis cartilage
- Femoral cartilage
- Traction
- Contrast
- Femur
Image Segmentation
Finite Element Discretization
Contact Stress During Walking
Gait Cycle

Normal

Dysplastic
Shape Variation

Mean Control Femur  

Mean Cam FAI Femur

-3.5 mm  3.5

Cortical Thickness

Max thickness of mean cam femur greater than mean control femur (3.57 mm vs. 1.38 mm) in anterolateral head neck junction
FEA Simulation Based on SSM
Results: Compressive Stiffness

Sliding contact between femur and rigid slab
Rigid Slab: 50 x 50
Penalty: 10000
Force: 10 unit
Number of nodes on Slab: 121
Total Force: 1210 unit
Mean Femur Effective Stress

Cam Mean Shape

Normal Mean Shape

Sliding Contact
Role of CIBC To Date

Extend Shapeworks to accommodate the necessary capabilities to address the scientific questions in our project.

Collaborate on integration of ShapeWorks with FEBio to allow the coupling of statistical shape modeling with subject-specific finite element analysis of hip mechanics.
Future Role of CIBC

Extend SSM capabilities to allow the modeling of specific geometric features of relevance to hip mechanics.

Extract clinically used measurements of shape directly from the ShapeWorks database.

Automate FE analysis of models based on shapes from the SSM database.

Index FE results to the SSM database so that new shapes can be analyzed with performing new FE analysis.