Clinical and Computational Collaboration in Orthopaedic Biomechanics

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The Comparative Orthopaedic Laboratory at the University of Missouri-Columbia (COL-UMC) has a three-fold mission: 1) To design and conduct the highest quality hypothesis-driven research focused on orthopaedic disorders of diarthrodial joints 2) To implement a comparative approach to investigation of joint disease in order to most efficiently and comprehensively address identified problems and discoveries. The mission of the Musculoskeletal Biomechanics Research Laboratory (MBRL) at the University of Missouri – Kansas City is to: Discover, disseminate, and utilize knowledge pertaining to the loading of joint tissues during dynamic activity. The (COL-UMC) also includes an internationally recognized team of scientists and clinicians while the MBRL, in conjunction with the UMKC Human Motion Laboratory, is comprised of biomedical engineers focused on musculoskeletal tissue mechanics and movement simulation.

Canine Model of Osteoarthritis—Meniscal Release

Osteoarthritis (OA) is a prevalent and debilitating disease for which there is no known cure. Evidence suggests that the biomechanical environment of the knee, which includes the interaction of tissues and neuromuscular forces, is strongly linked to OA pathomechanics for both the initiation and progression phases of disease. The meniscal release is a biomechanically-induced unicompartmental model of canine OA that produces pathology in the joint very similar to what occurs in the knee of most humans that have OA.

The procedure includes a complete radial transection of the medial meniscus in the caudal horn near its junction with the caudal meniscal collateral ligament.

Collaboration Goal: Use biomechanical measurement and multiscale computational modeling techniques to predict the changes in joint and tissue level loading of the meniscal release procedure.

Multibody Model of Meniscus and Cartilage

Experimental tissue testing is used to determine properties for computational multibody models of joint structures.

Deformable contacts between the various geometries are calibrated from experimental data and are modeled by the following formula:

\[ F = k_0 \delta^{m} + B \delta \]

Where \( \delta \) is the interpenetration of geometries and \( k_0 \), \( \alpha \), and \( B \) are stiffness, force exponent, and damping coefficients respectively.

Experimental Data was collected using non invasive techniques. Modeling techniques were used to match the behavior during contact.

Model Creation. The result is a multibody model of the flexible component with its parameters calibrated against the experimental performance.

Field Elements are 6 axis spring/dampers that are used to simulate the flexible behavior of the meniscus and cartilage. The properties of these elements are calibrated statistically from material testing in semiphysiological loading.

Gait Measurements

- Shear force of foot on force plate
- Vertical force of foot on force plate
- Muscle activation of Sartorius (hip flexion)
- Muscle activation of Rectus Femoris (hip flexion, knee extension)
- Muscle activation of Gastrocnemius (ankle extension, knee flexion)
- 3-D motion of markers attached to body segments is recorded during gait.

Musculoskeletal Model

Gait measurements, tissue models, and limb models will be used in a musculoskeletal model of the canine hind limb. Developed modeling techniques will be used to predict cartilage stress before and after the meniscal release procedure during gait.

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