



**2009 OTA Annual Meeting
Manchester Grand Hyatt
San Diego, CA**

Basic Science Focus Forum

**Symposium IV:
Recent Innovations in Biomechanical Investigations**

Douglas D, Level I

**3:00pm – 4:20pm
Wednesday, October 7, 2009**

**Moderators: Loren L. Latta, PhD
Steven A. Olson, MD**

**Faculty: Louis E. DeFrate, PhD
Neil A. Sharkey, PhD**

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Disclosure: Faculty disclosure can be found starting on page 67 of the 2009 OTA Annual Meeting program.

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Kinematic Motion Analysis

Measuring kinematics important to:

- Understanding how injury alters normal joint biomechanics
- Understanding how surgical treatments can restore normal function
- Explaining potential mechanisms contributing to osteoarthritis

However, it is important to evaluate kinematics under physiologically relevant loading conditions

Our approach is to use imaging techniques to measure joint motion directly in patients under weight-bearing loading conditions

Chronic Lateral Ankle Instability and Osteoarthritis: An *in vivo* biomechanical analysis

Lateral ankle sprains

- Are one of most common injuries in sports and reasons for emergency room visits (Valderrabano 2006, Rosenbaum 1997)
- Most commonly involve injury of anterior talofibular ligament (ATFL)
- Most patients recover with time

Chronic lateral ankle instability and osteoarthritis

- 10 - 40% of patients experience chronic symptoms including: pain, instability, loss of range of motion, poor proprioception, and onset of early osteoarthritis— particularly on anteromedial talus (Hintermann 2002, Valderrabano 2006)
- Abnormal ankle motion after injury thought to contribute to OA (Valderabano 2006, Taga 1993)
- Kinematic changes after lateral ankle ligament injury under *in vivo* loading conditions are not well understood

Measuring kinematics of ankle joint in patients with lateral ankle instability under *in vivo* loading conditions

- Both ankles MR imaged at 3T to create 3D models of injured and healthy contralateral ankles, including articular surface of cartilage
- Ankles imaged using biplanar fluoroscopy to quantify ankle motion under *in vivo*, weight-bearing loading
- Models matched to fluoroscopic images to reproduce 3D ankle motion
- Cartilage surfaces used to approximate cartilage contact strains

Lateral ankle instability alters in vivo ankle biomechanics

- Lateral ankle instability increases anterior tibial translation and internal rotation of talus
- Altered kinematics result in increase and anteromedial shift of peak cartilage contact strains, to a region where OA is observed clinically (Valderrabano 2006, Omori 2004)
- Altered biomechanics may predispose ankle to degenerative changes

The effects of ACL graft placement on in vivo knee motion

Anterior cruciate ligament reconstruction offers good short term results

- However, recent studies suggest that ACL reconstruction has limited ability to prevent degenerative changes (Lohmander 2007, Fithian 2002)
- Altered kinematics might contribute to joint degeneration
- Recent studies have questioned the ability of transtibial techniques to restore anatomy of ACL—resulting in vertical graft
- Tibial tunnel independent techniques more closely restore ACL anatomy
- Effects of graft placement on in vivo motion not well understood

Measuring kinematics and graft deformation in patients with transtibial and tibial tunnel independent techniques

- Both knees MR imaged at 3T to create 3D models of knee, including location of graft and ACL attachment sites
- Knees imaged using biplanar fluoroscopy to quantify joint motion under in vivo knee flexion from 0 to 90°
- Models matched to fluoroscopic images to reproduce 3D knee motion
- Position of attachment sites used to measure graft deformation

More anatomically placed grafts better restore knee biomechanics

- Grafts placed transtibially resulted in grafts that are longer and more vertically oriented than ACL
- Grafts placed independently of the transtibial tunnel more closely mimicked native ACL
- As a result, grafts placed independently of the tibial tunnel more closely restored normal knee motion compared to grafts placed transtibially
- Altered knee motions might contribute to degenerative changes observed after ACL reconstruction

ONE STEP AT TIME: SOMES LESSONS LEARNED FROM DYMANIC LOADING OF CADAVER EXTREMITES

Neil A. Sharkey

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Cadaver experimentation is a valuable component of musculoskeletal research because internal biomechanical behavior can be accurately measured without harm to patients. Properly designed studies can also explore relationships between external variables, such as those typically measured in the gait assessment laboratory, and internal parameters such as tissue strain and bony kinematics. In addition, investigations using cadaver material are amenable to efficient experimental designs that afford direct comparison of multiple experimental conditions or procedures within the same subject, thereby offering the advantage of good statistical power with relatively low experimental numbers. Despite their advantages, cadaver models are generally rather simplistic and often fail to accurately reproduce *in-vivo* loading environments. More specifically, cadaver models of the foot and ankle function have frequently consisted of static axial loads applied to the tibia with the foot plantigrade as it would be in two-legged stance. Applied loads are often low compared to those in life, and muscle forces are either absent altogether or low compared to *in-vivo* forces.

Over the past several years we and others have been working to overcome some of these deficits and in so doing have produced increasingly sophisticated devices expressly designed to better reproduce the normal loading environment of the foot and ankle. Our most recent efforts have culminated in a model called the Robotic Dynamic Activity Simulator or RDAS; an apparatus that uses computer controlled actuators together with kinematic and electromyographic data taken from live subjects to re-animate cadaver extremities under carefully controlled experimental conditions. The RDAS and its predecessors have enabled us to more fully examine the internal mechanics of the foot under normal and pathologic conditions. This presentation will review some performance characteristics of our model while exploring some interesting results hailing from past experiments.

In particular we will briefly examine how the extrinsic muscles of the foot and related soft tissue structures modulate skeletal stress and strain; explore factors implicated in the generation of metatarsal and tibial stress fractures; describe the kinematic consequences of malleolar fracture and repair, and better define the role played the flexor hallucis longus in normal and pathologic loading of the first metatarso-phalangeal joint.

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Micromechanics: Energy of Injury on a Smaller Scale

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- 1) Energy of Injury – Many ways to describe an injury, one of the more common distinctions is high energy vs low energy. Many subjective opinions, few objective definitions and methods.
- 2) Work in human fractures: Severity assessment and other techniques
- 3) A closed model of articular fracture offers an opportunity to measure energy of injury directly

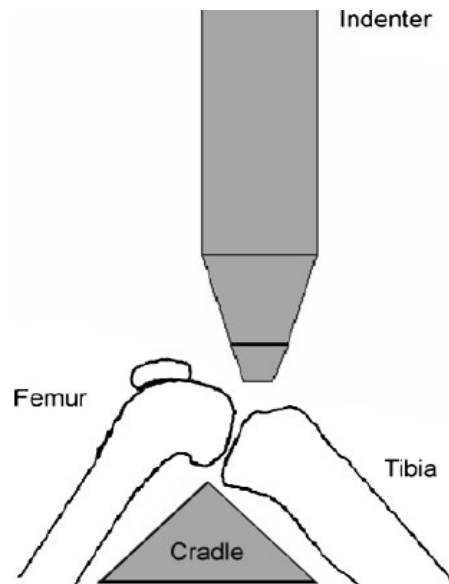
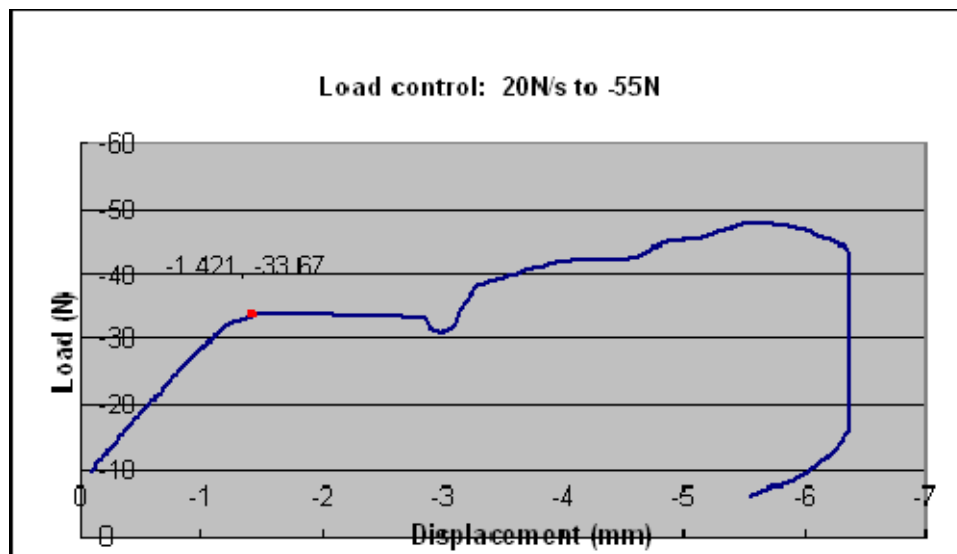
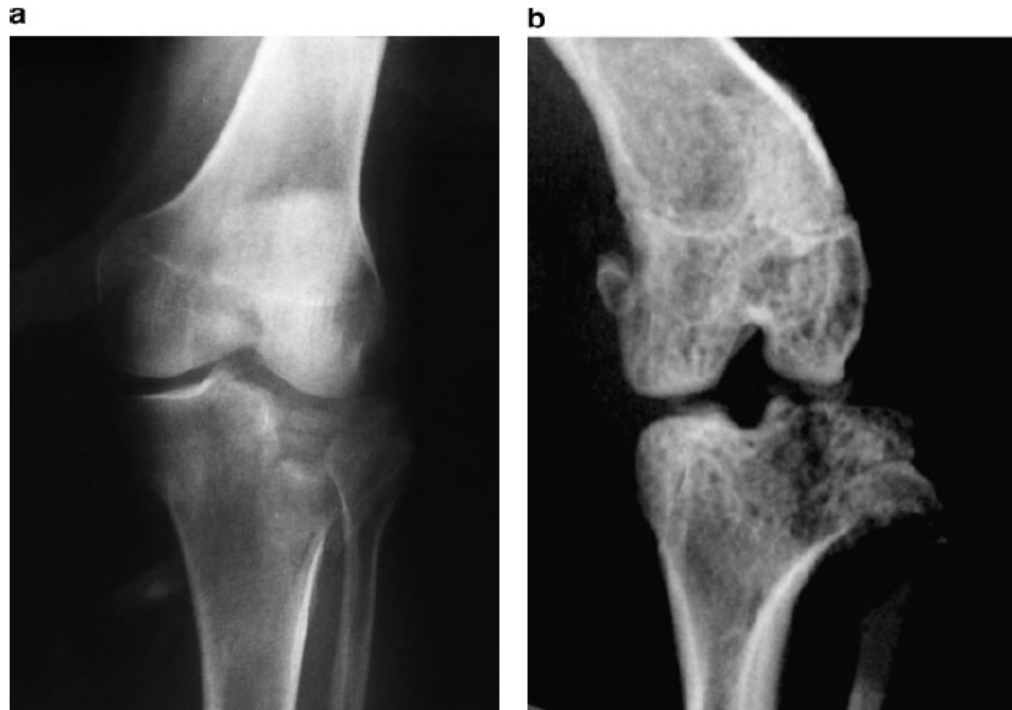


Illustration of loading frame and indenter used for fracture creation



Load vs Displacement curve for creation of closed articular fracture



a Human tibial plateau fracture with split –depression injury components, b mouse tibial plateau fracture from closed indenter injury model.

- 4) Injury energy of injury analysis for the mouse model
- 5) Other technique to assess energy of injury.

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