

Reproducibility in Experimentation

Erdemir Laboratory

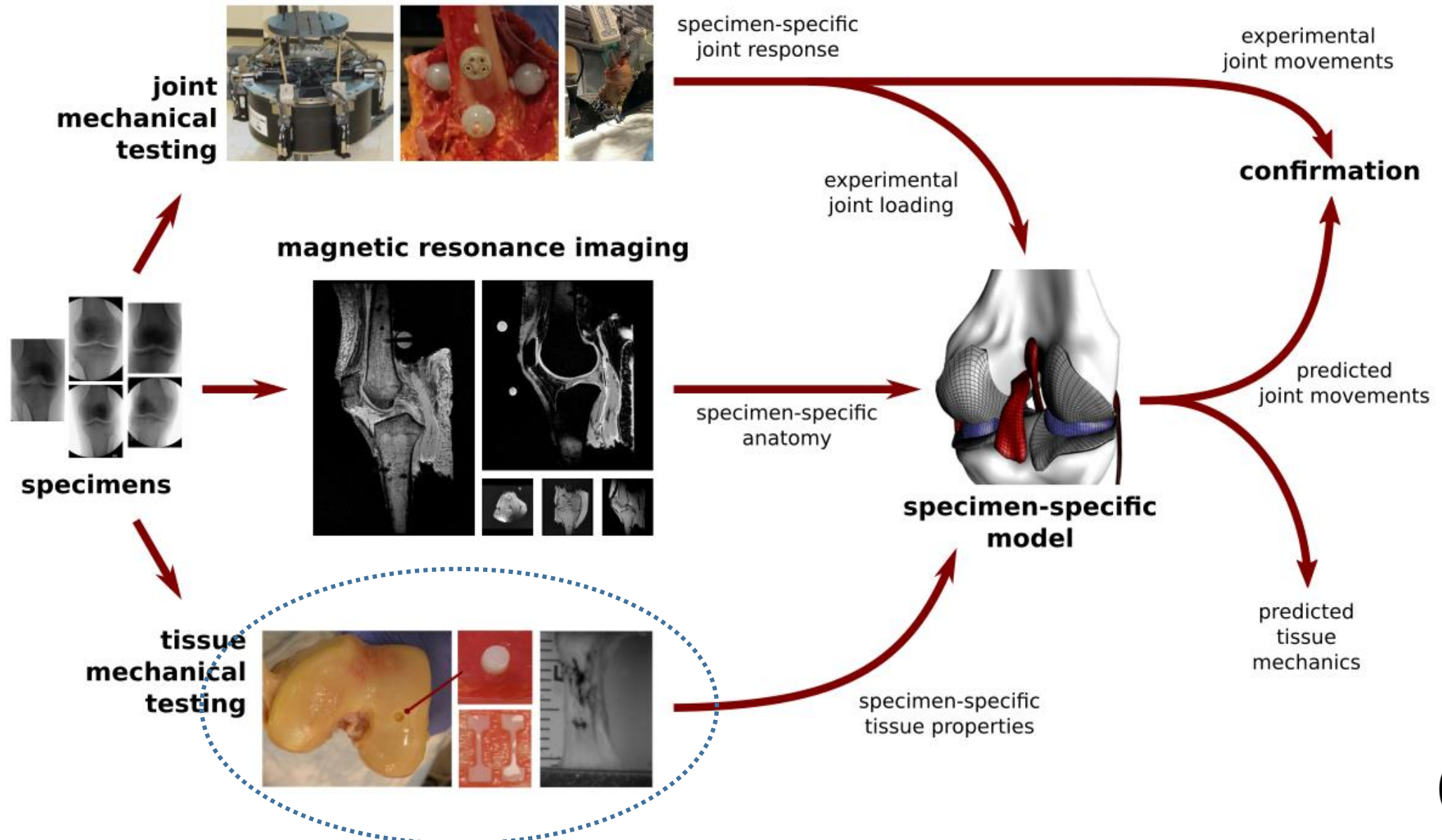
Department of Biomedical Engineering

Lerner Research Institute

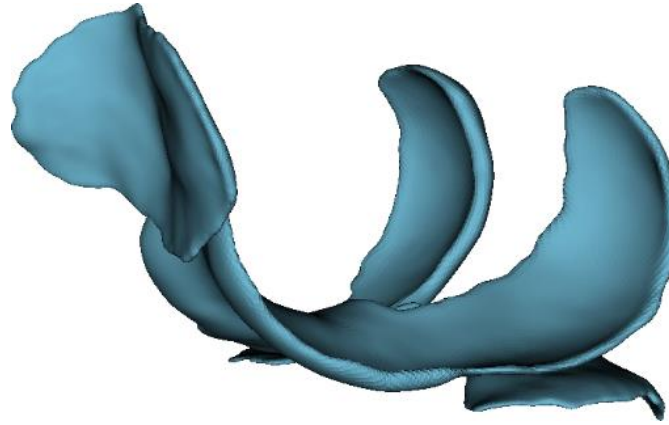
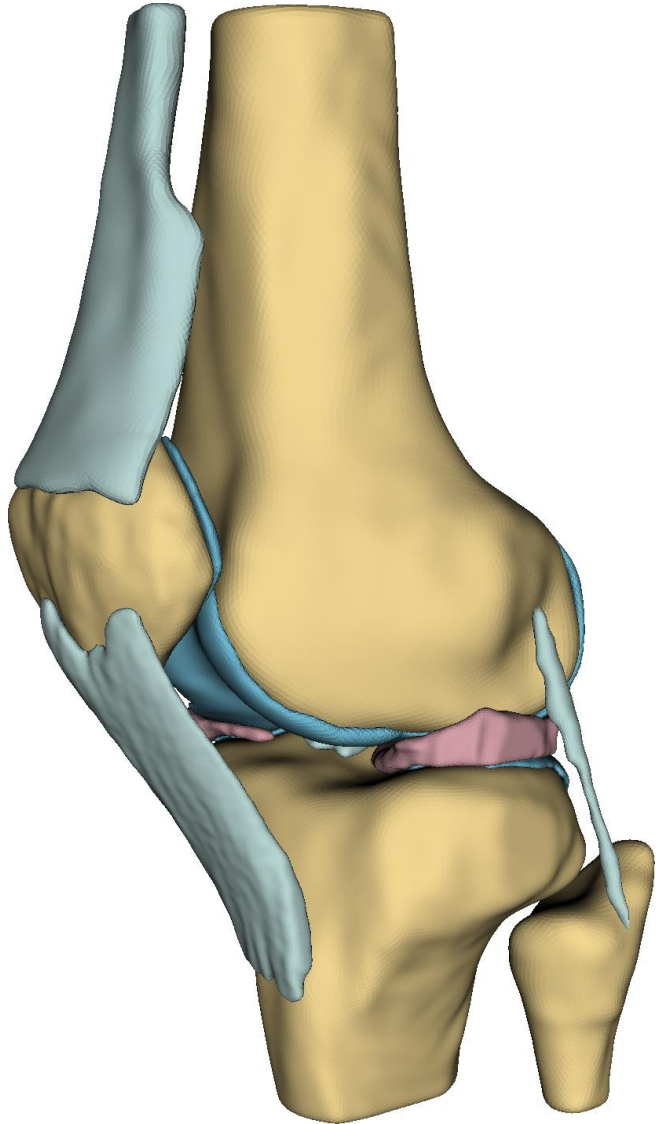
Cleveland Clinic

Dec 11, 2020

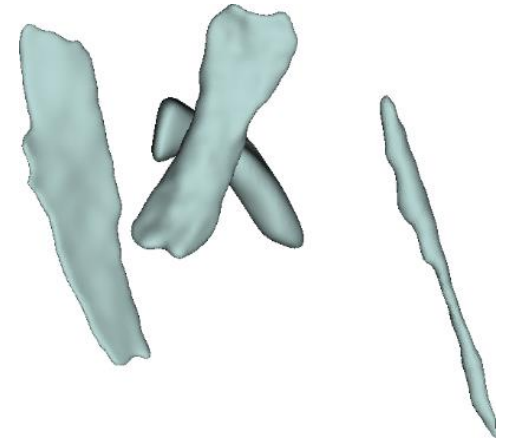
Need



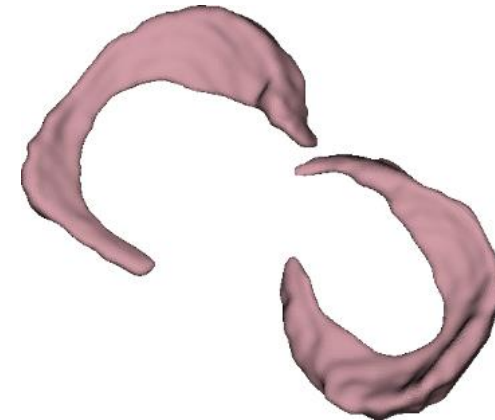
Tissues of Interest



Cartilage



Ligaments



Menisci

Literature

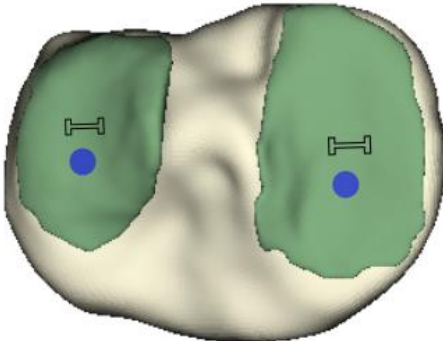
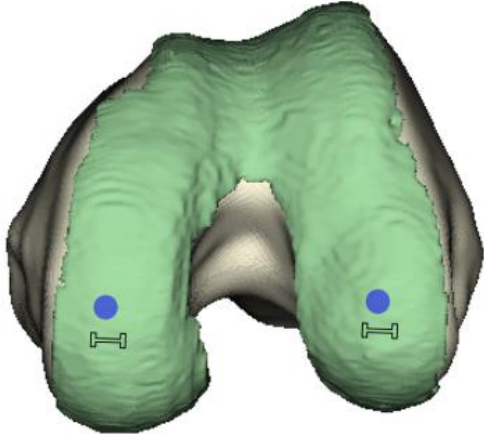
- Experimentation is resource intensive
 - Most modeling studies rely on literature for material properties
 - Literature is vast
 - Diverse protocols
 - Reported properties have large range
 - Experimentation details are often incomplete
 - Numerous parameters can affect the testing outcomes
 - Material representations often require multiple test types
- ❖ *Reproducibility and repeatability of experimental procedures is rarely reported*
 - ❖ *No uniform testing standards for tissues*

Goals

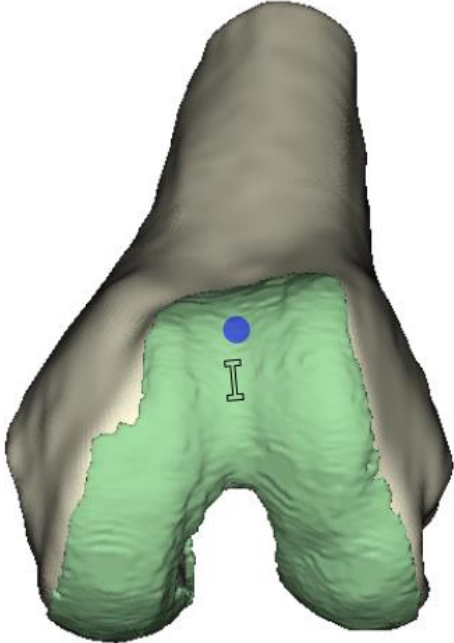
- ❑ Create a comprehensive testing protocol
- ❑ Test and document its repeatability

Cartilage

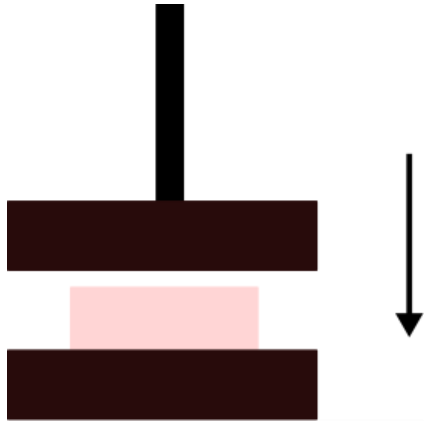
Lateral



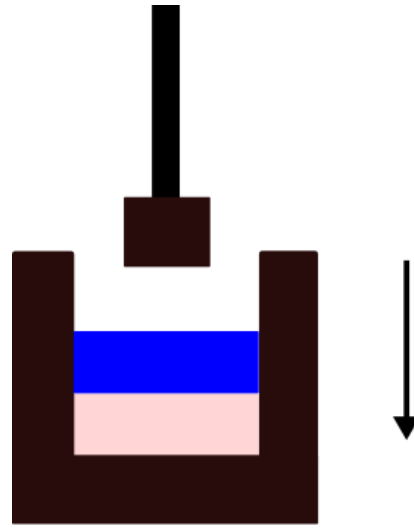
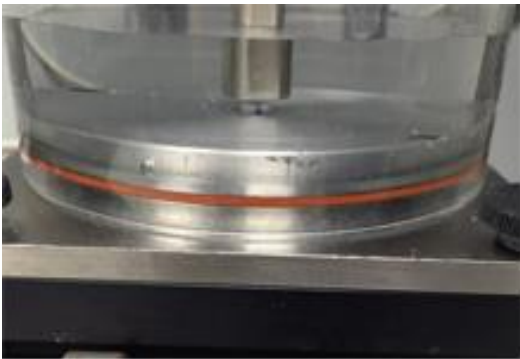
Medial



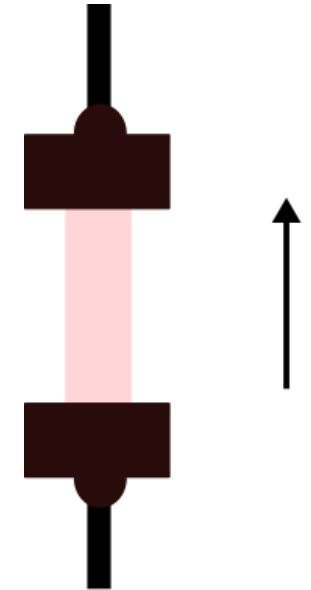
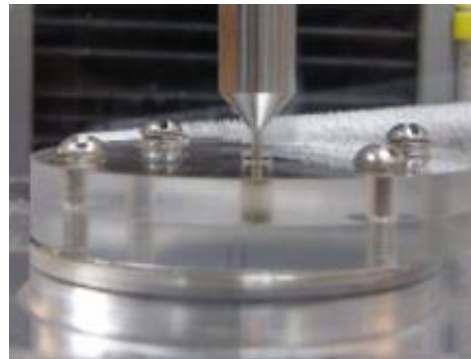
Types of Tests



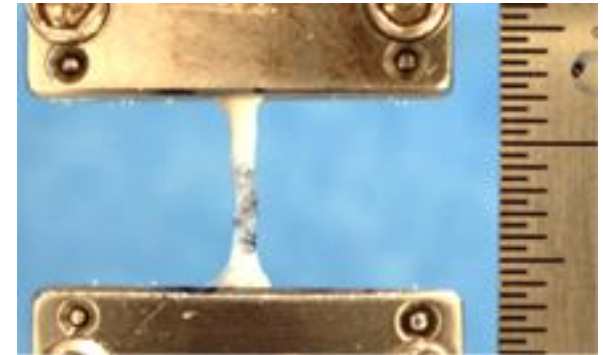
Unconfined compression



Confined compression

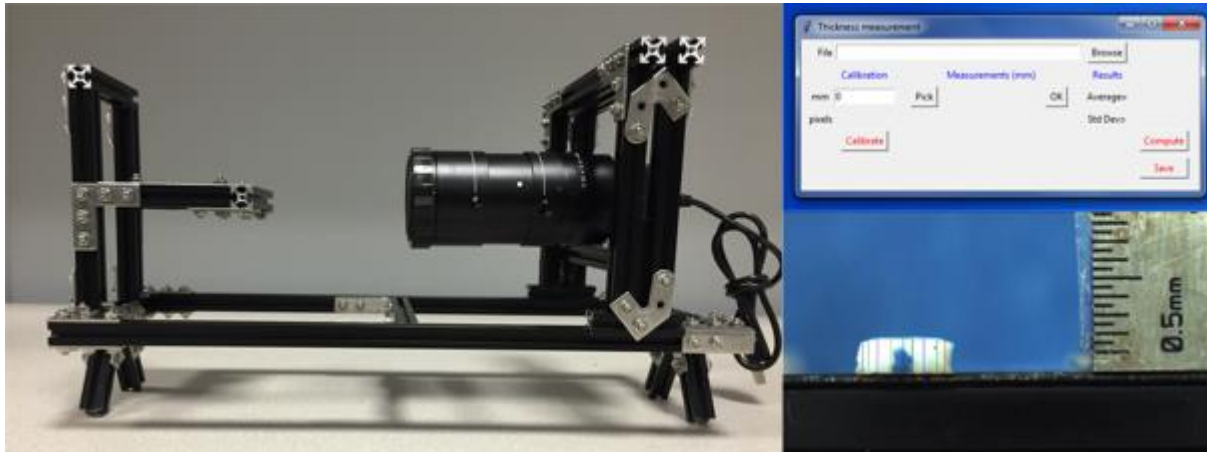


Uniaxial tension



Test Set-up

- Test environment – room temperature, PBS
- Specimen dimensions – 5 mm diameter (compression), 5 mm by 1 mm (tension)
- Minimum freeze thaw cycles

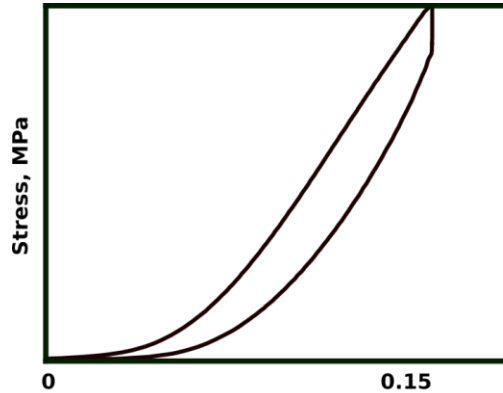


Optical thickness measurement



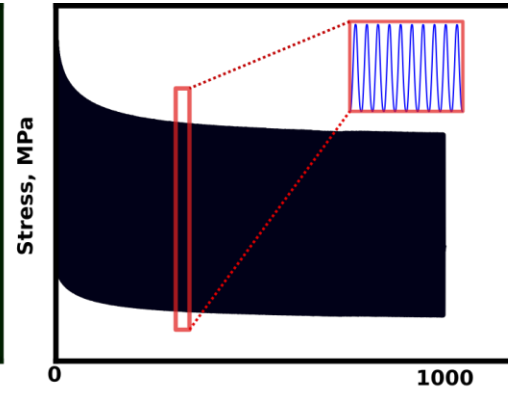
Testing machine

Testing Protocol



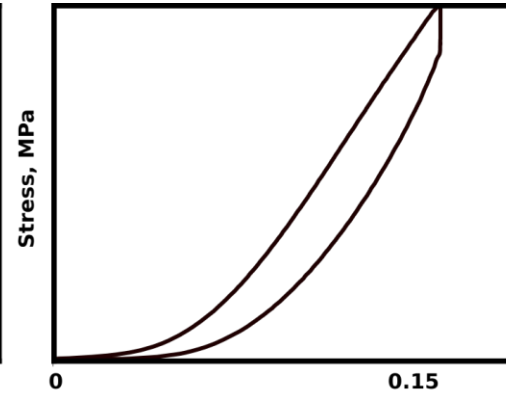
(a)

Loading and unloading to 15 % strain at 20%/s



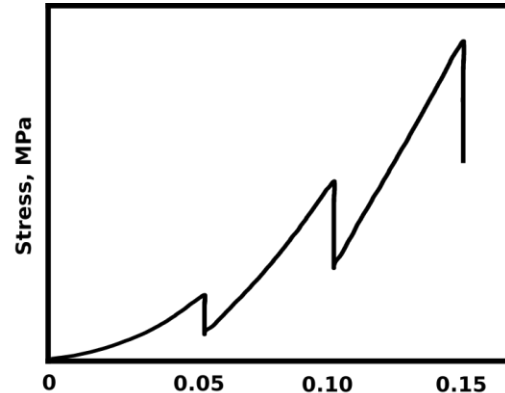
(b)

Preconditioning between 10-15% strain at 2Hz



(c)

Loading and unloading to 15 % strain at 20%/s



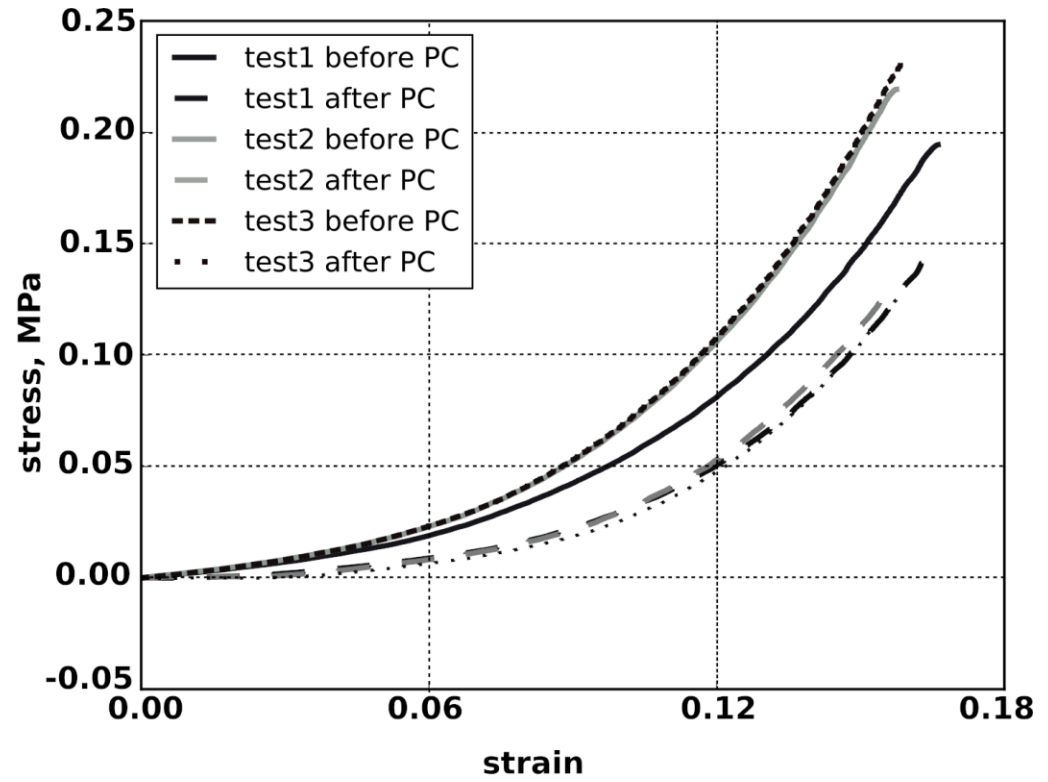
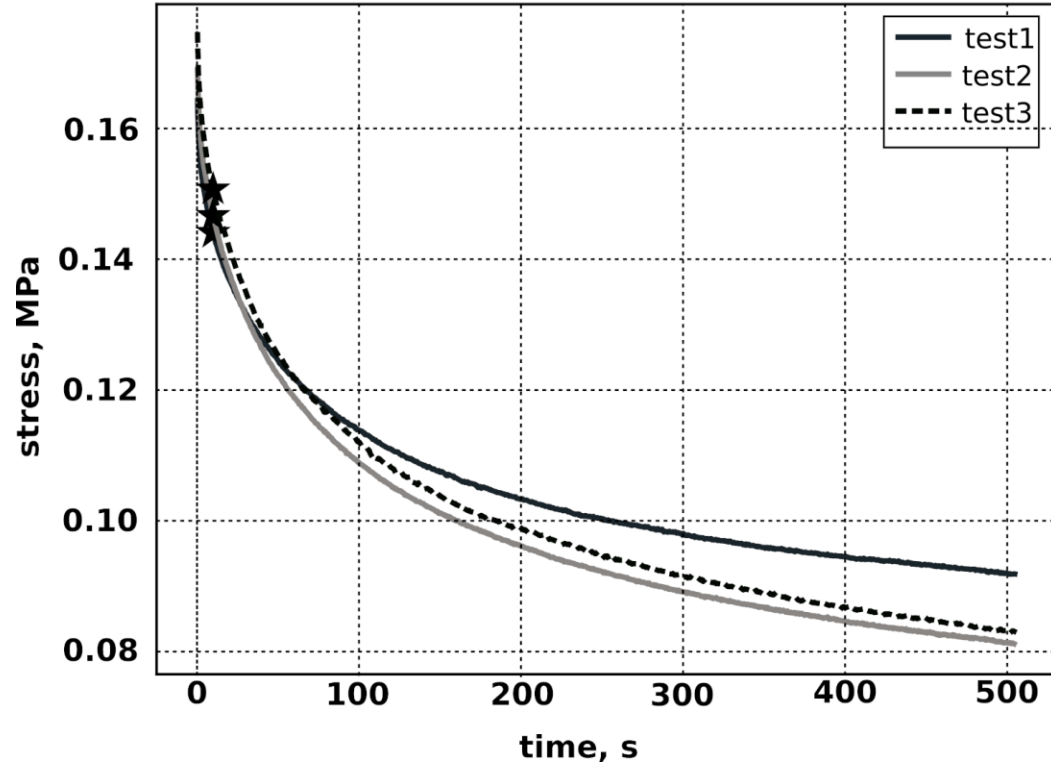
(d)

Multi-step stress relaxation. 5-10-15% strain at 20%/s, 30 min hold after each step

Repeatability

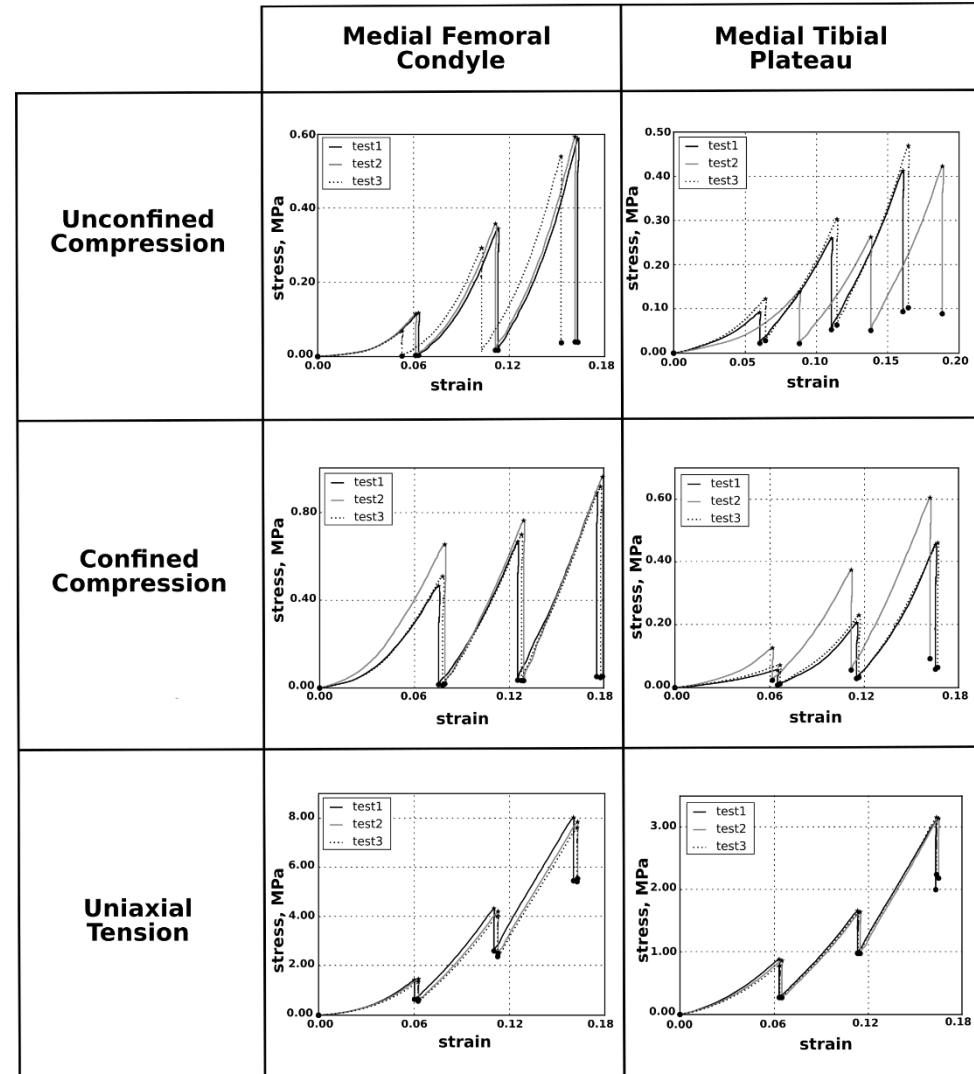
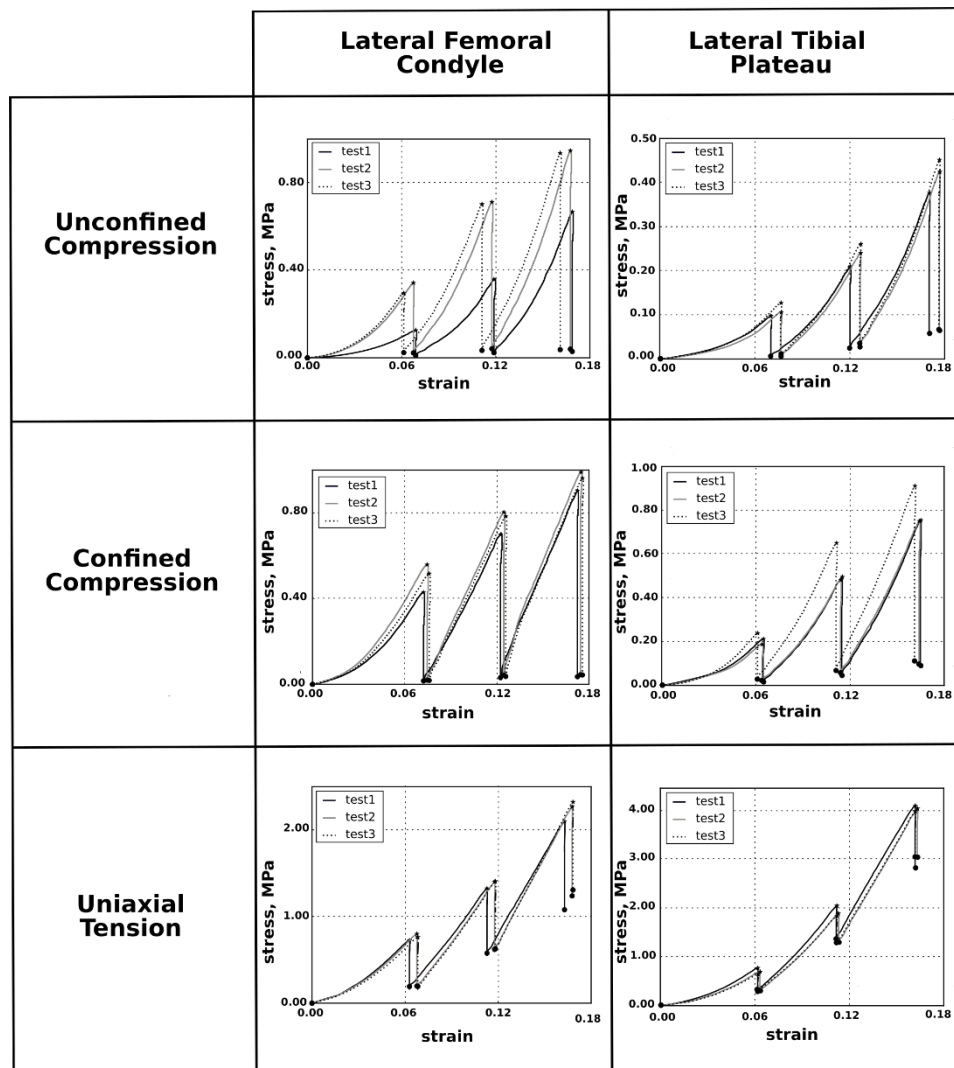
- ❖ Each test repeated three times
- ❖ Set up completely dismantled after each test
- ❖ Specimen refrigerated until retesting
- ❖ 12 samples / 18 tests / 54 total tests with repetitions

Results



Patella, Unconfined compression

Results

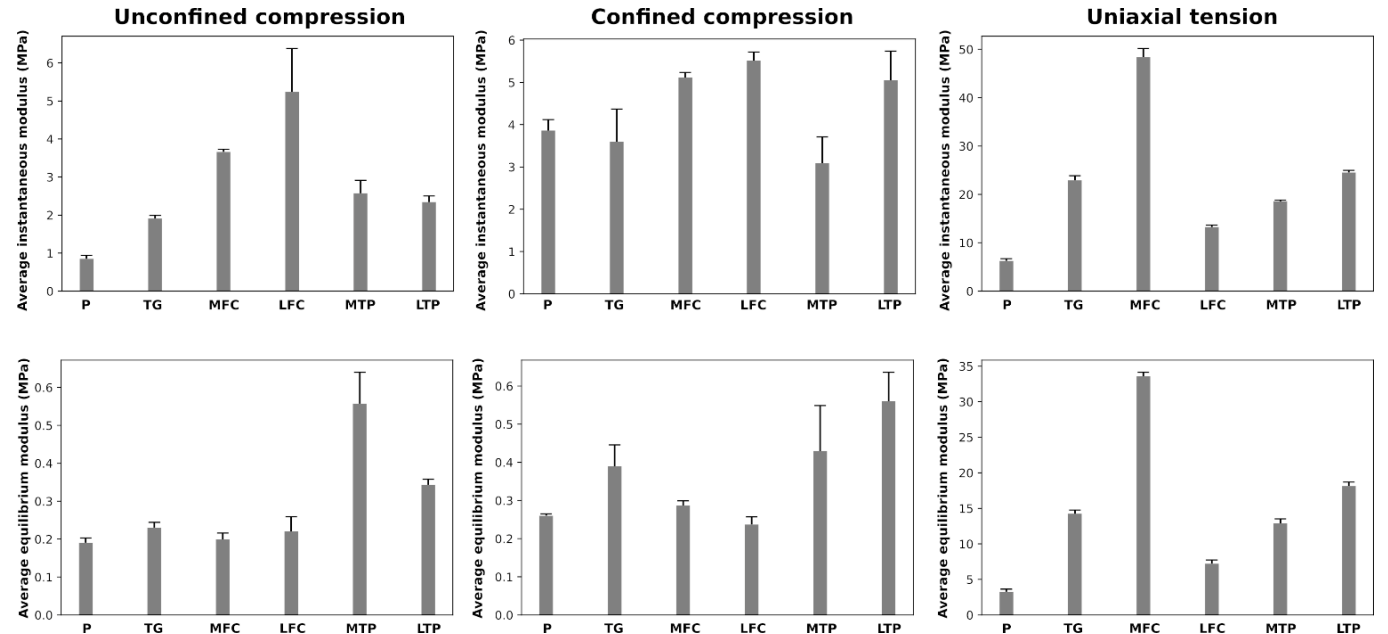


Discussion

- Comprehensive protocol produced repeatable results
- Results fit within the envelope of reported properties
- Location dependent variations

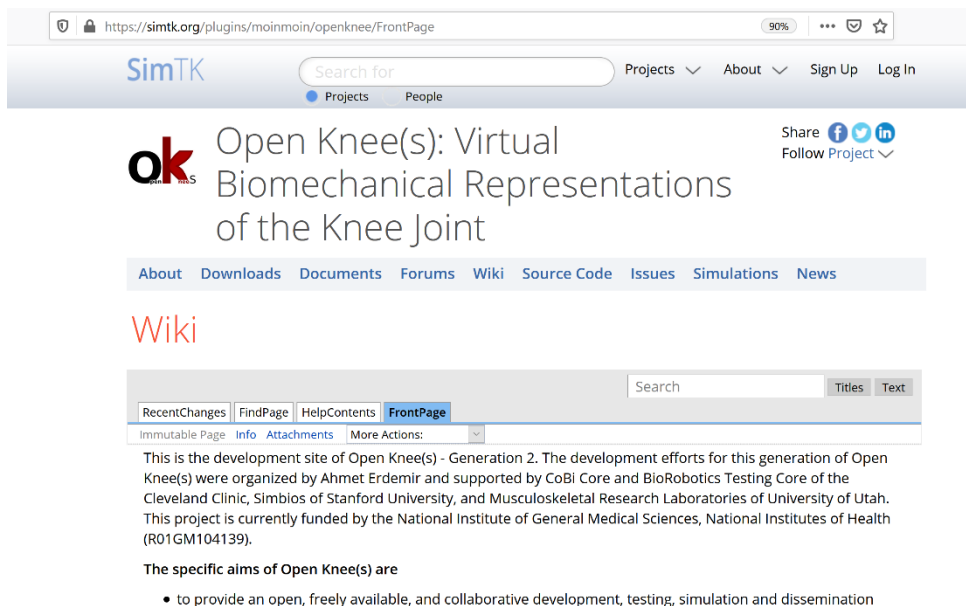
Limitations

- One specimen
- One representative sample from each load bearing location



Wrapping up

- Standardization of testing procedures is necessary
- Selecting values from literature will become less arbitrary
- Quantification of errors associated with testing parameters will be helpful in decision making

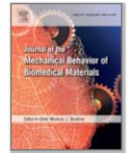


The screenshot shows the SimTK website interface. The URL is <https://simtk.org/plugins/moinmoin/openknee/FrontPage>. The page title is "Open Knee(s): Virtual Biomechanical Representations of the Knee Joint". The page includes a search bar, navigation links (About, Downloads, Documents, Forums, Wiki, Source Code, Issues, Simulations, News), and a "Wiki" section. The Wiki content states: "This is the development site of Open Knee(s) - Generation 2. The development efforts for this generation of Open Knee(s) were organized by Ahmet Erdemir and supported by CoBI Core and BioRobotics Testing Core of the Cleveland Clinic, Simbios of Stanford University, and Musculoskeletal Research Laboratories of University of Utah. This project is currently funded by the National Institute of General Medical Sciences, National Institutes of Health (R01GM104139). The specific aims of Open Knee(s) are" followed by a bullet point: "to provide an open, freely available, and collaborative development, testing, simulation and dissemination".



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A comprehensive testing protocol for macro-scale mechanical characterization of knee articular cartilage with documented experimental repeatability

Snehal Chokhandre, Ahmet Erdemir  

Acknowledgments



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