Poroelastic and Intrinsic Viscoelastic Dissipation in Cartilage

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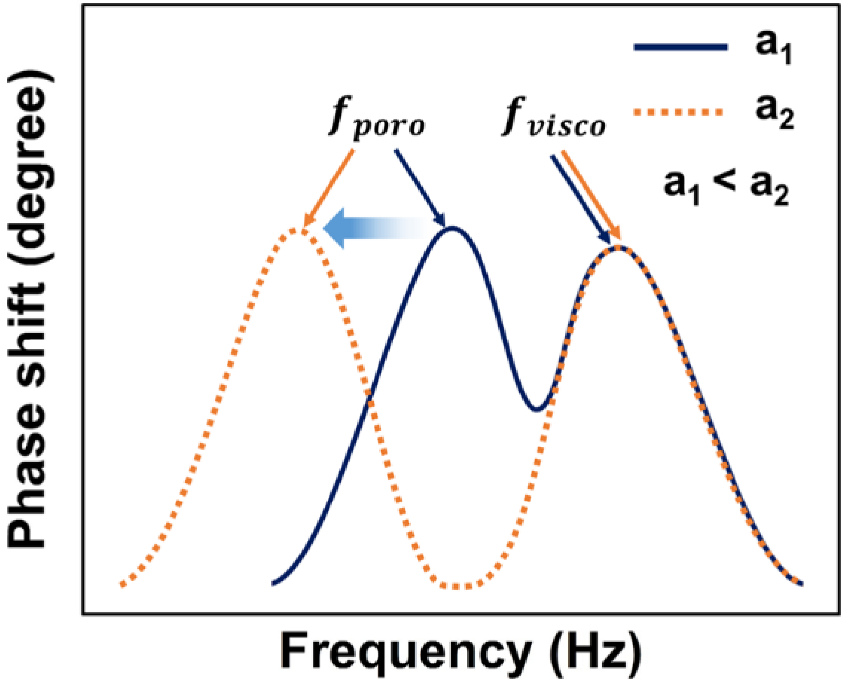
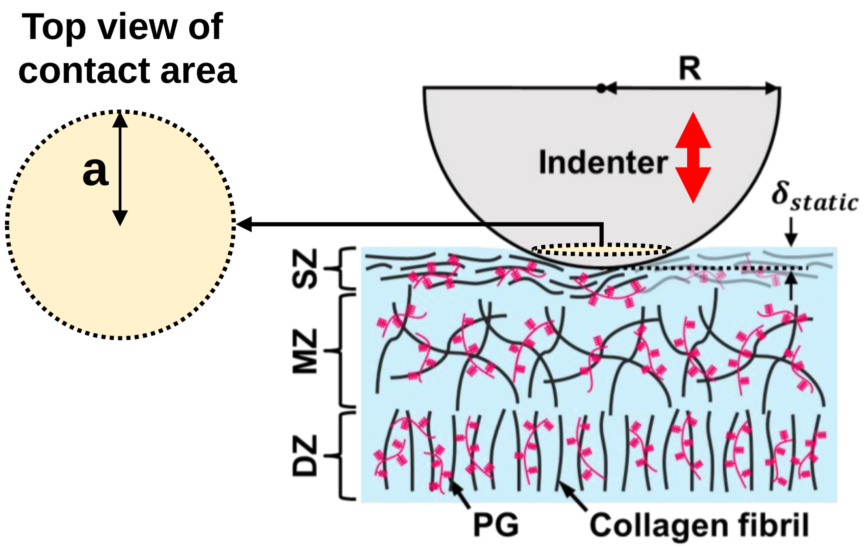
Introduction: dynamic testing

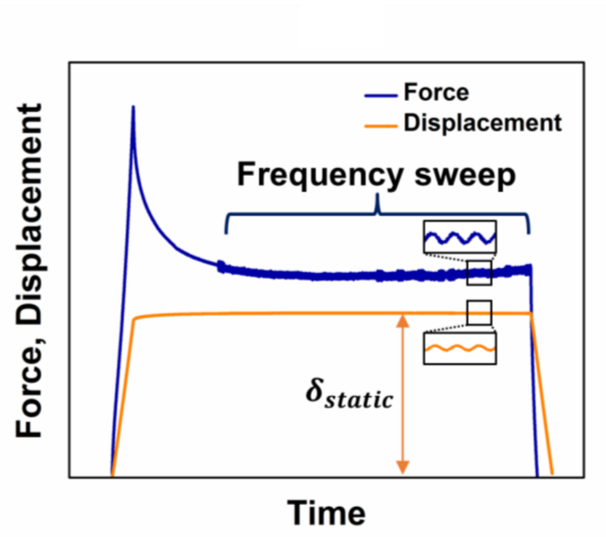
- **Articular cartilage is a connective tissue that functions as a load-bearing and dissipative material over a broadband spectrum of loading frequency.**
- **The main aim of this study is to understand the origin of cartilage's broadband dissipation behavior by uncoupling the poroelastic and intrinsic viscoelastic dissipation mechanisms through their dependence on characteristic lengths.**
  - Poroelasticity-driven dissipation is dependent of characteristic length.
  - Viscoelasticity-driven dissipation is independent of characteristic length.



Characteristic lengths:
a_1 and a_2

Methods: dynamic testing





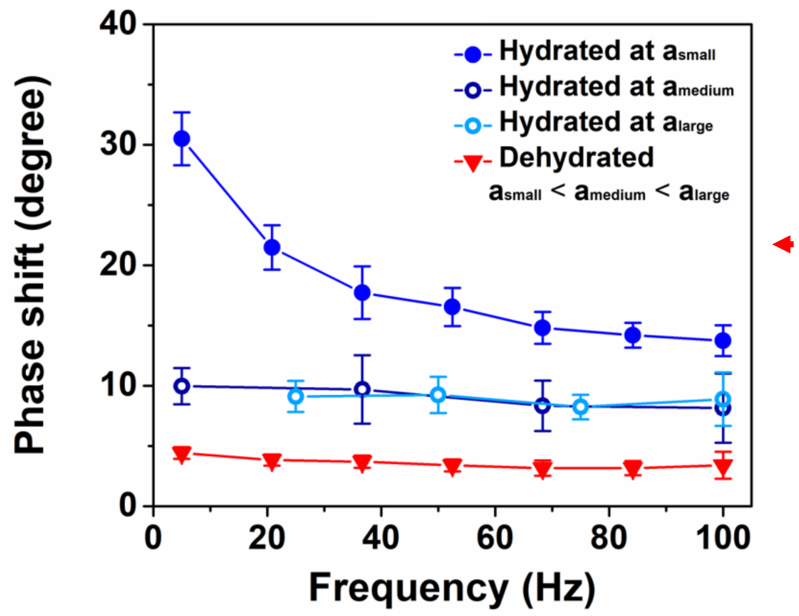
For hydrated cartilage with Dulbecco's Phosphate-Buffered Saline.

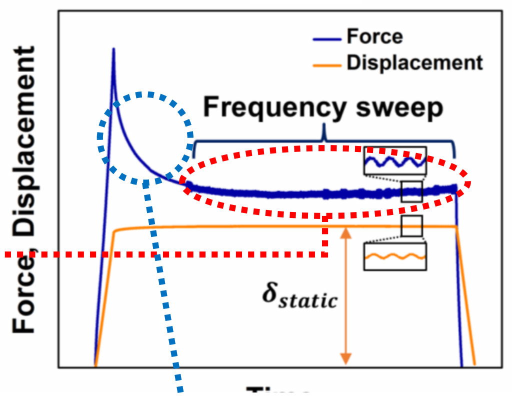
- **Frequency range: 5 – 100 Hz (25 – 100 Hz for a_{large})**
- **Three different contact radii: a_{small} (~ 13 μm) < a_{medium} (~ 33 μm) < a_{large} (~ 43 μm)**
  (R = 50 μm for a_{small} and R = 1 mm for a_{medium} and a_{large})
- **Oscillation amplitude: 0.5 – 2 nm**

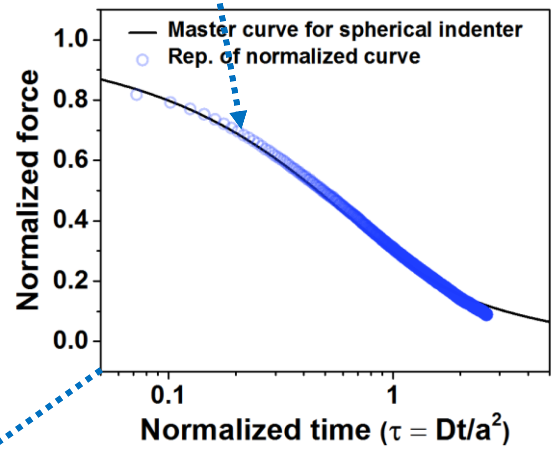
For dehydrated cartilage (after 5 hours of dehydration ; ~ 25 % of wet weight)

- **Contact radius: ~ 6 μm**

Results & Discussion: dynamic testing







- **a_{medium} and a_{large} were from dominant-viscoelastic dissipation.**
  - Independency of phase shift on contact radius
- **a_{small} was from poroviscoelastic dissipation.**
  - Dependency of phase shift on contact radius
  - Frequency-dependent trend ($f_{poro} = \frac{D}{a^2}$ =0.22±0.09 Hz)
- **Dehydration of cartilage decreased the overall phase shift.**

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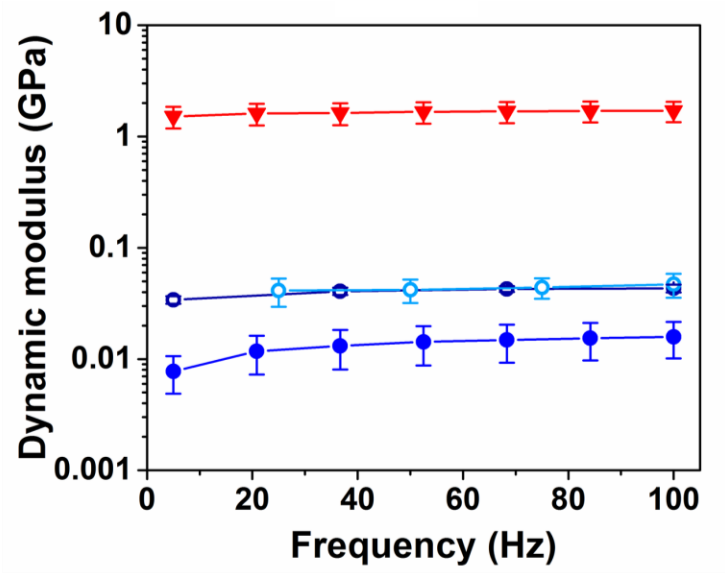
Results & Discussion: dynamic testing



- **Self-stiffening of cartilage was larger at a_{small} (poroviscoelasticity) compared to a_{medium} and a_{large} (viscoelasticity).**
- **a_{small} (poroviscoelasticity) showed lower dynamic modulus than that tested at a_{medium} and a_{large} (viscoelasticity).**
  - Cartilage was compressible at a_{small}, underpinned by poroelastic dissipation (volumetric effect)
  - Cartilage was likely to deform isochorically at large contact radii (a_{medium} and a_{large}).
- **Dehydration significantly increased dynamic modulus.**

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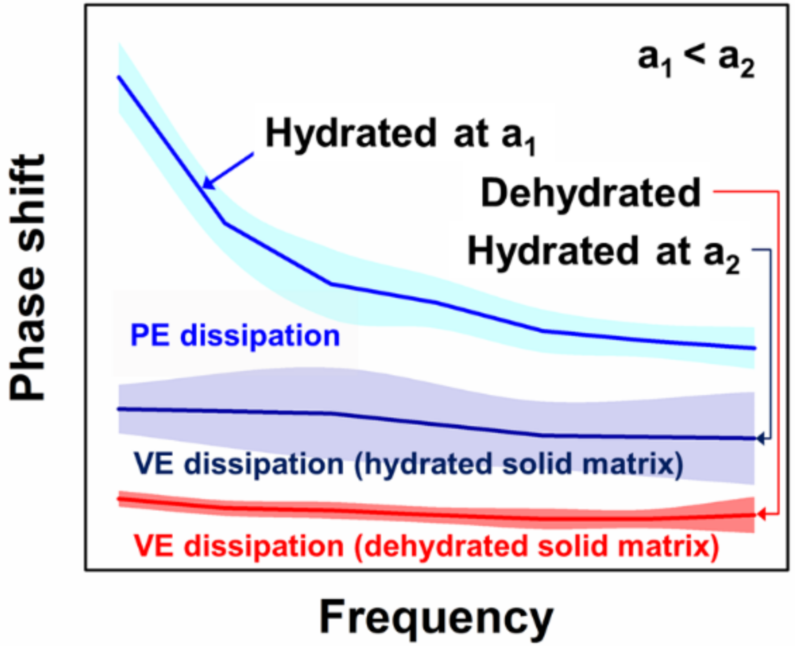
Conclusions: dynamic testing



- Dissipative properties due to poroelasticity and intrinsic viscoelasticity of cartilage were investigated over physiological loading frequencies.
- Intrinsic viscoelasticity provides baseline of broadband dissipation.
- Poroelasticity additionally increases overall dissipation at small scale lengths
- Decreased dissipation in dehydrated cartilage showed the importuned decreased viscoelasticity as well as poroelasticity.
- These findings can be used to design cartilage-like broadband dampers.

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Thank you! Q&A

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