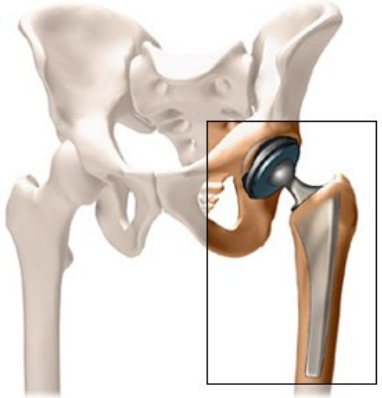
Monitoring Femoral Component Insertion in Cementless Total Hip Arthroplasty



Source: www.webmd.com/DW/arthritis/aa14678.asp (Jul 2004)

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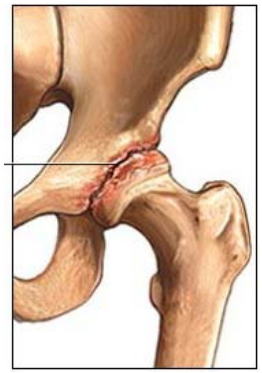
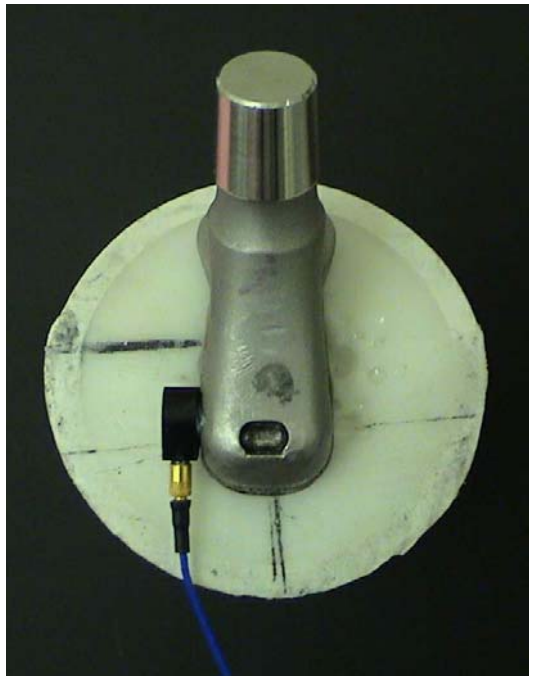
Los Alamos NATIONAL LABORATORY

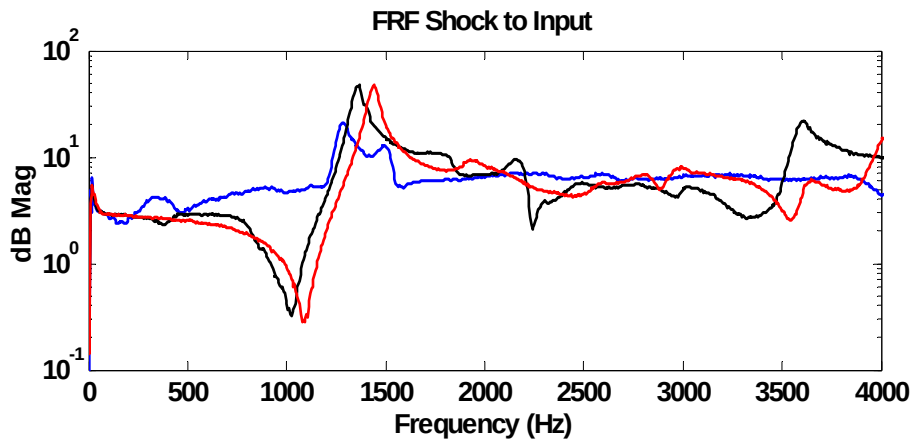
Damage detection techniques were used to analyze a femoral component



Problem Statement

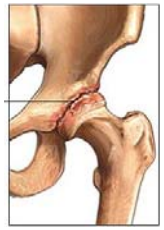
Experimentation





Analysis

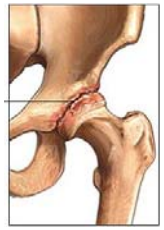
Hip Surgery can drastically improve quality of life

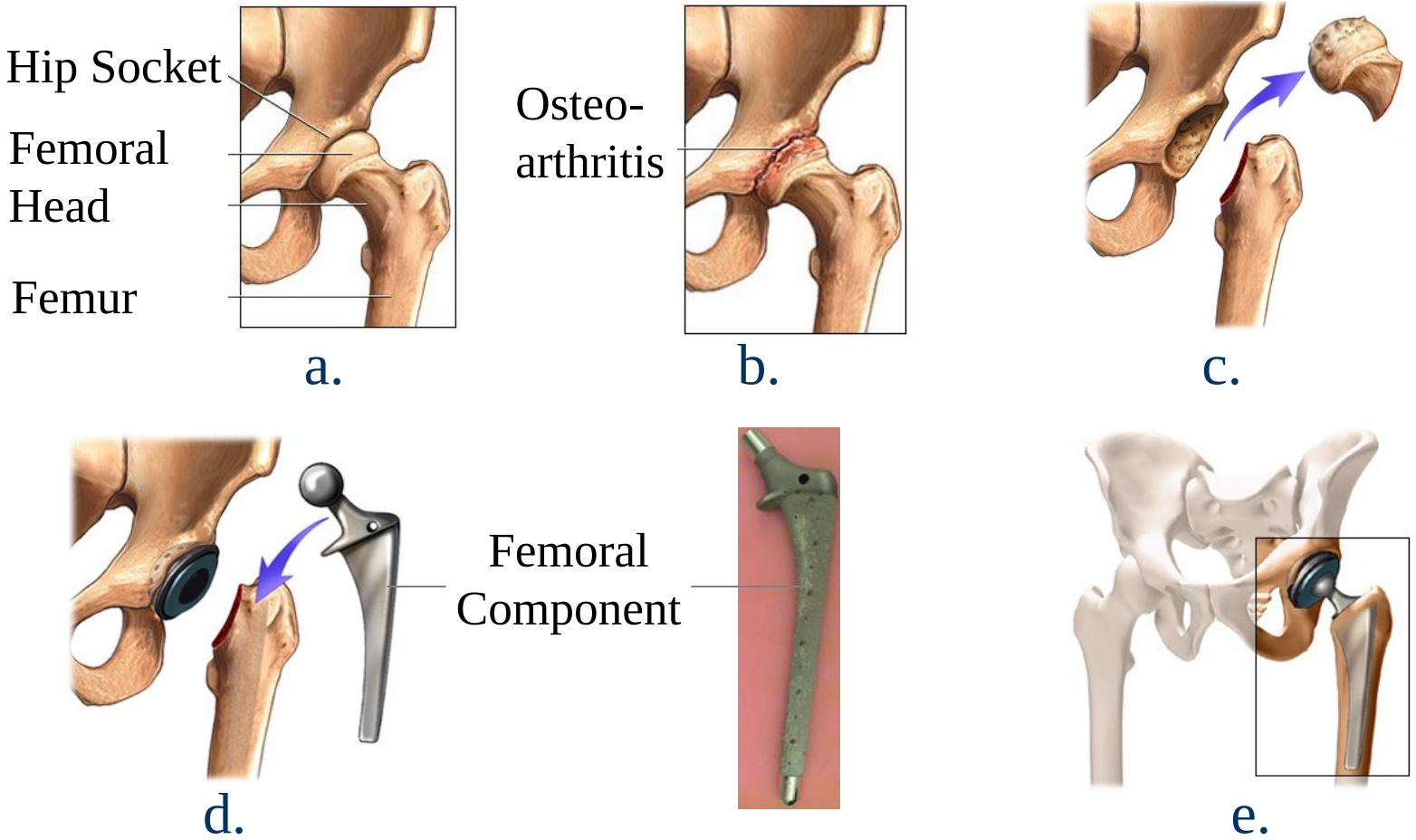


- Primary Conditions
  - Osteoarthritis
  - Rheumatoid Arthritis
  - Traumatic Arthritis
- Secondary Conditions
  - Pulmonary Embolism
  - Pneumonia

Source: orthoinfo.aaos.org (Oct 2004)

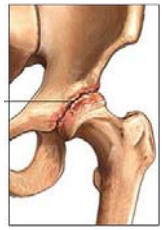
The background of the current surgical technique





Source: www.webmd.com/DW/arthritis/aa14678.asp (Jul 2004)

The goal is to prevent hoop stress damage



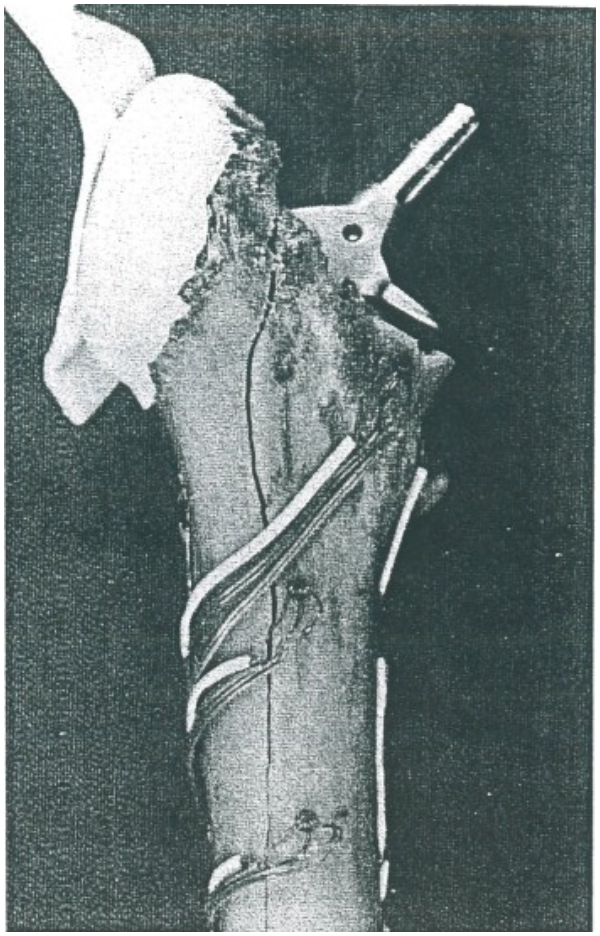
Over insertion causes excessive hoop stress

↓

Fracture

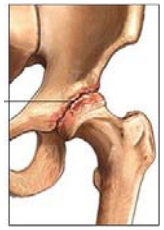
↓

Increased incidence of revision



Source: Jasty (p 485)

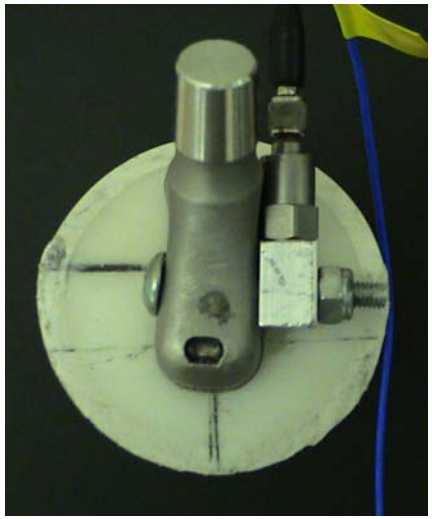
The less invasive trend in surgery has benefits and disadvantages



Smaller incision

- Decreased field of view → Risk of fracture
- Less tissue trauma → Quicker recovery

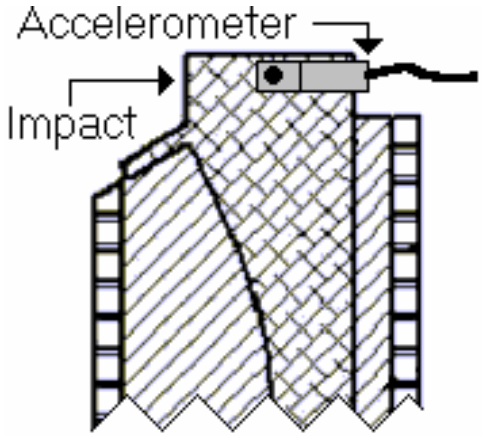
The experimental configuration for this study



Suspended at each end with foam between wood blocks

PCB 500g shock accelerometer model 350B04

Collecting data during stages of seating



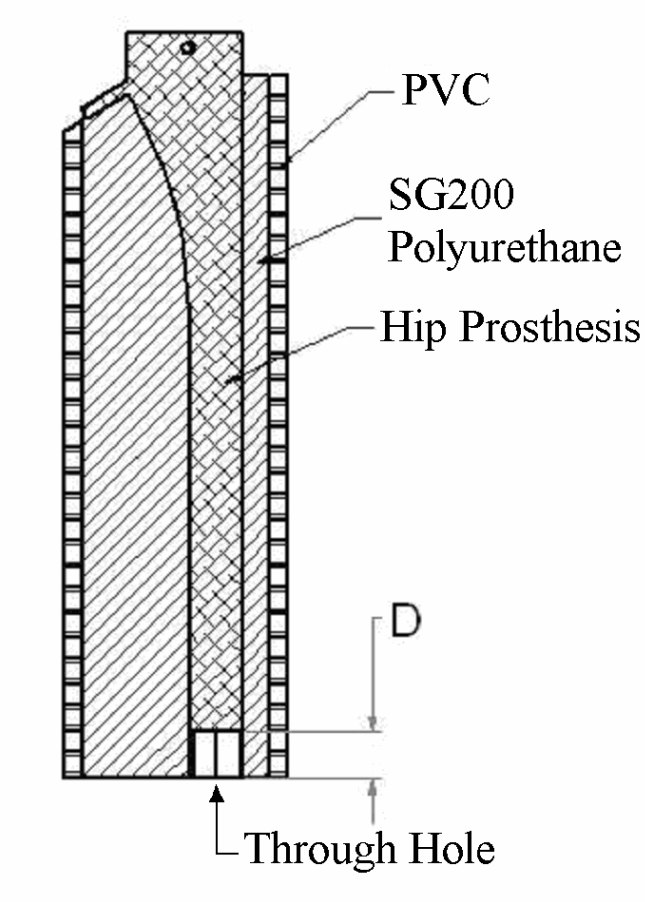
Source: www.PCB.com (Oct 2004)

PCB modal hammer model 086C05

Impact configuration

Data Set 1: 7 depths, 5 averages each depth, 10 hits per average
Data Set 2: 8 depths, 5 averages each depth, 10 hits per average

The first and last measurements were taken at the following depths

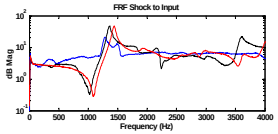


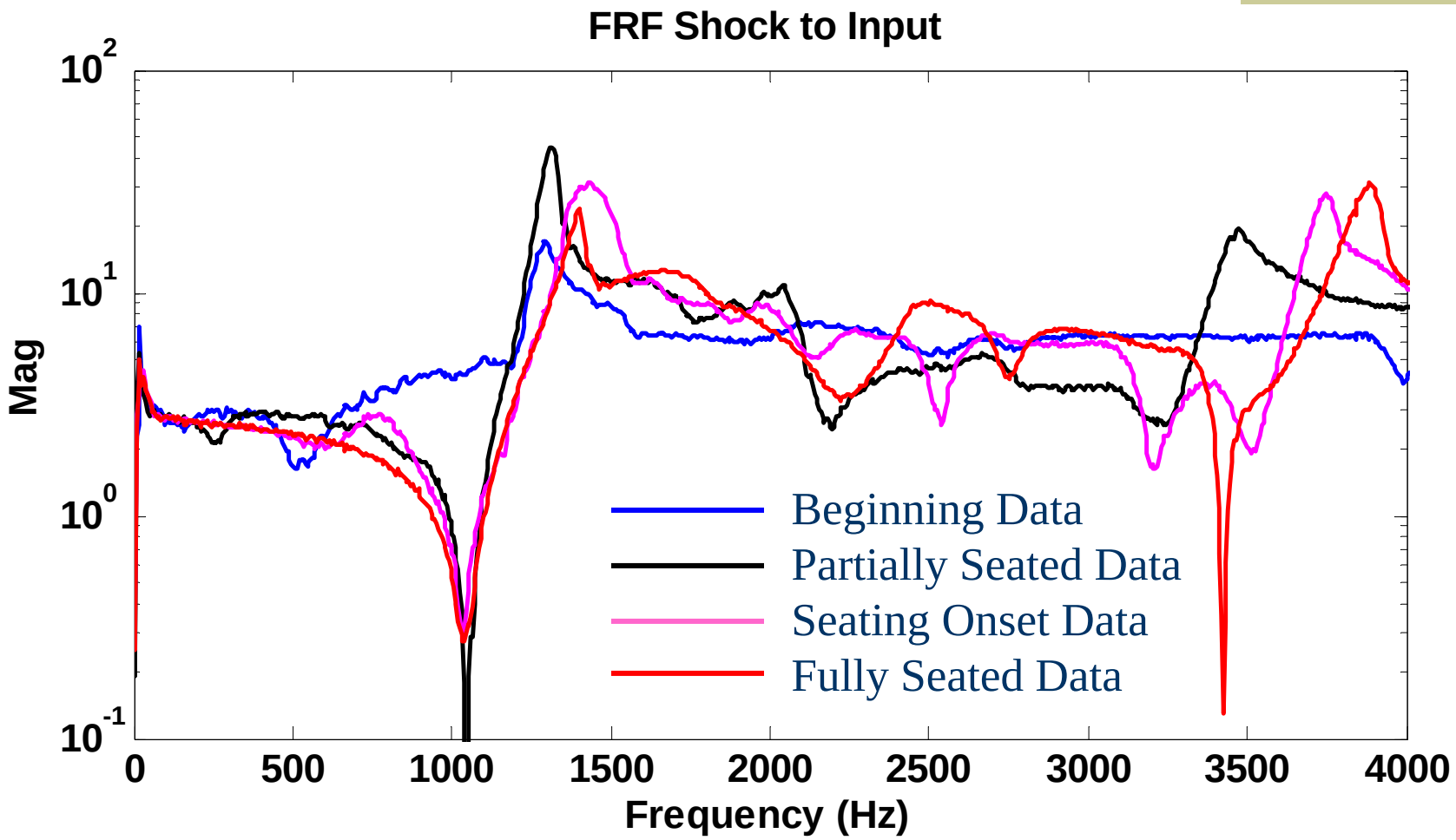
Depth 1:
3.18 cm
(1.25 in)

Depth n-1:
2.62 cm
(1.03 in)

Depth n:
2.62 cm
(1.03 in)

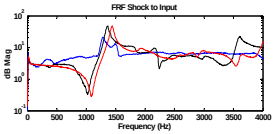
The depth of the component can affect the FRF





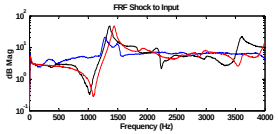
Data analyzed in MATLAB

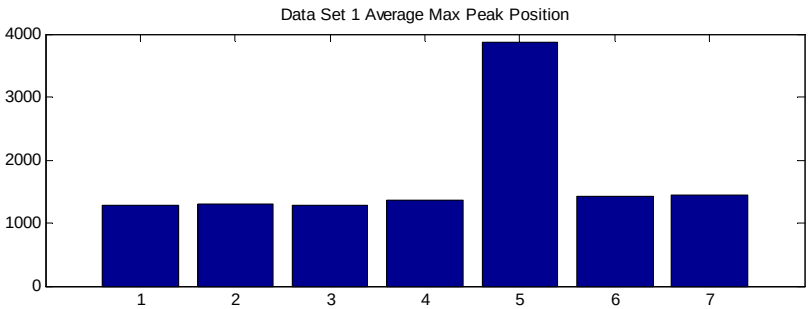
Three methods of analysis were used

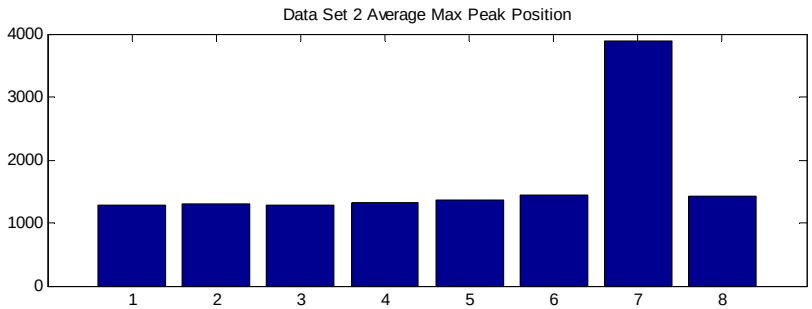


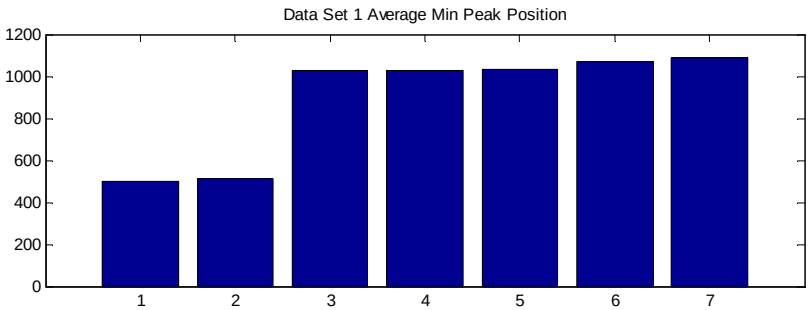
- Largest Resonance and Anti-resonance
- Spectral Moments
  - $M_n = \int_{\omega_i}^{\omega_f} \omega^n f(\omega) d\omega$
- Global Holder (Lipschitz) Exponent
  - $Log(Mag) = \alpha Log(\omega) + K$

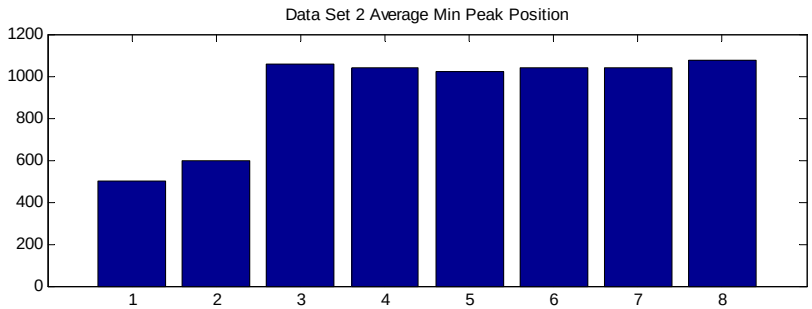
Resonance/anti-resonance location at each depth inconclusive





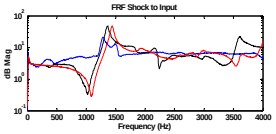






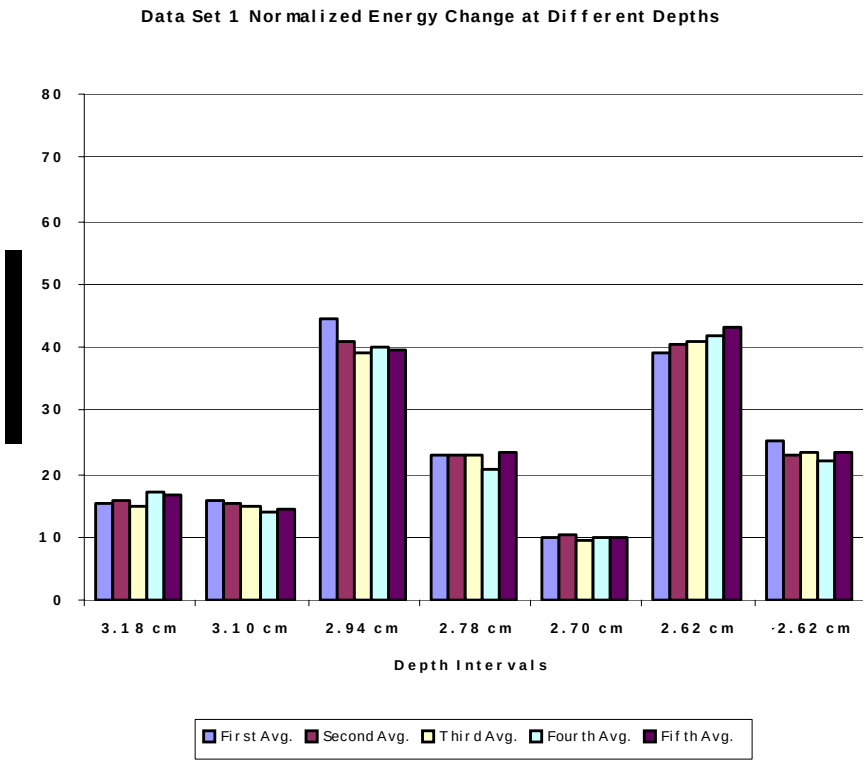
No trends are observed in the location of the resonance and anti-resonance at each depth when viewed across data sets.

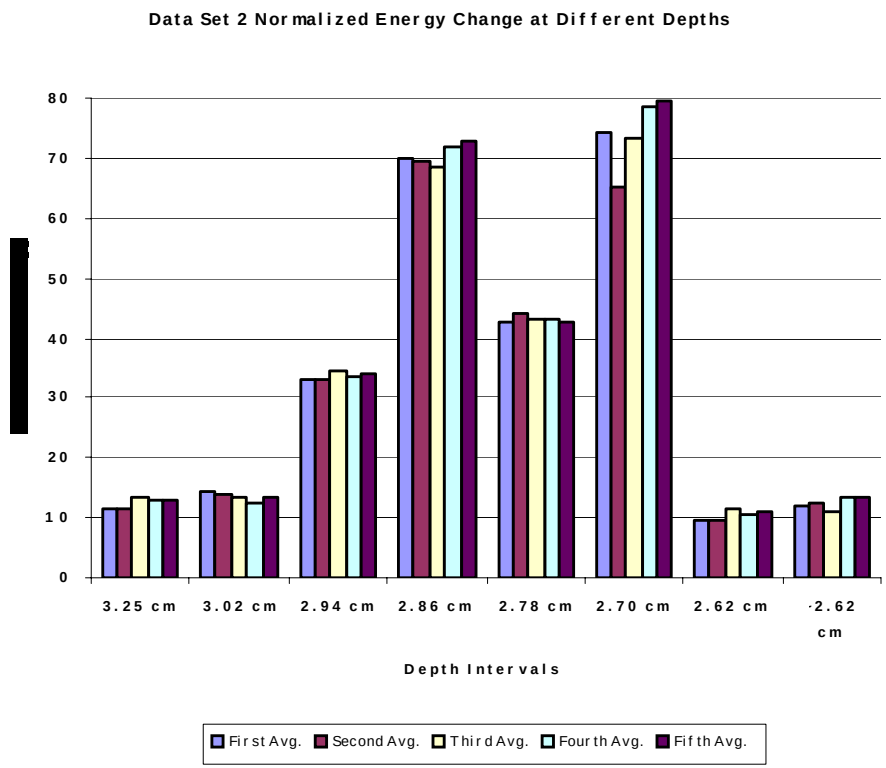
Spectral Moments yielded physical characteristics of FRF



Normalized Energy Change at Each Depth.

$$M_0 = \int_{\omega_i}^{\omega_f} \omega^0 f(\omega) d\omega$$

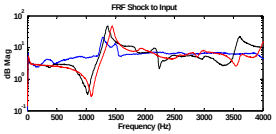




Data Set 1 7 unique depths

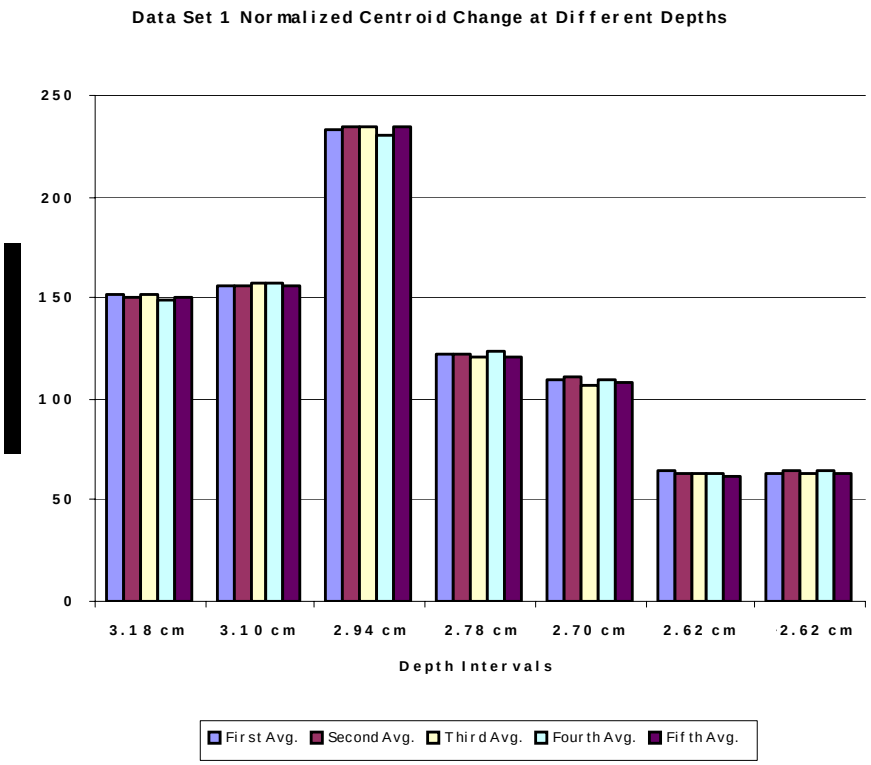
Data Set 2 8 unique depths

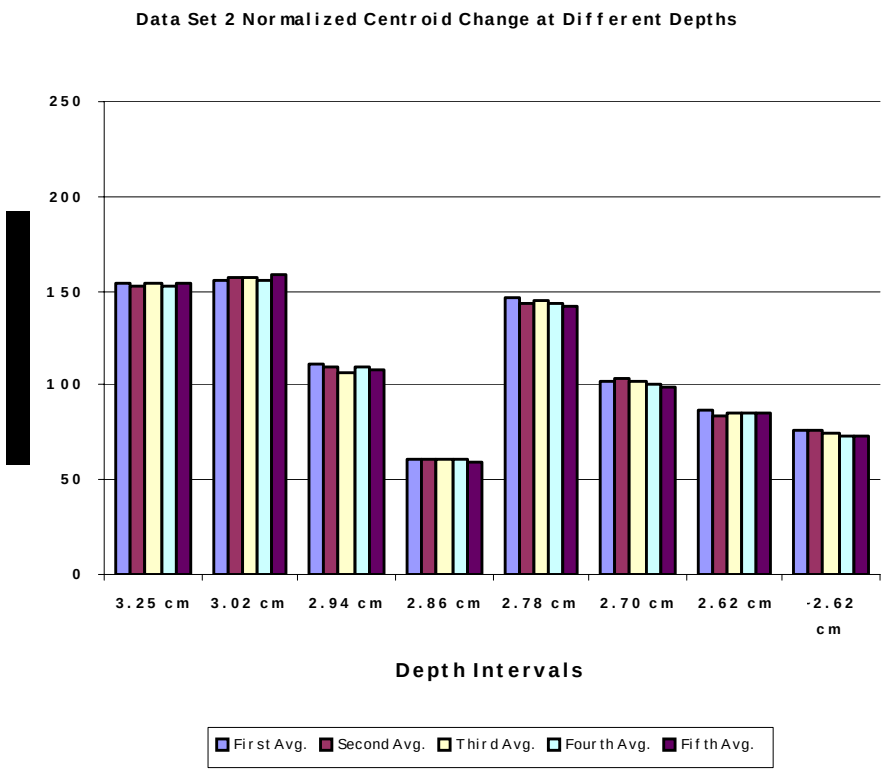
Spectral Moments yielded physical characteristics of FRF



Normalized Centroid Change at Each Depth.

$$M_1 = \int_{\omega_i}^{\omega_f} \omega^1 f(\omega) d\omega$$

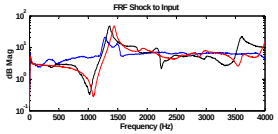


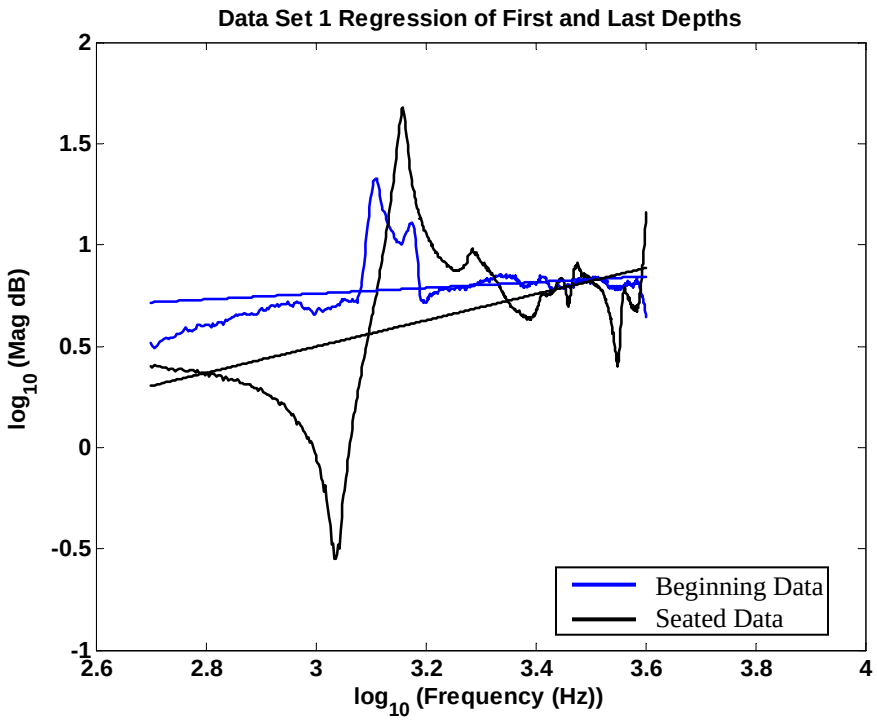


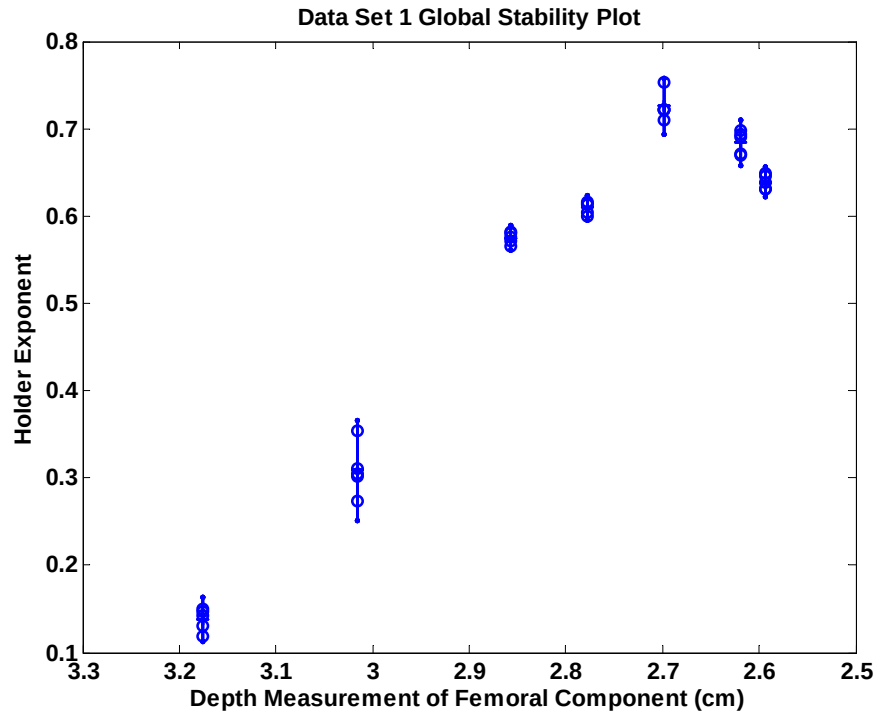
Data Set 1 7 unique depths

Data Set 2 8 unique depths

Global Holder exponent proved to be best predictor of seating







$$Log(Mag) = \alpha Log(\omega) + K$$

Conclusions

- Several trends correlating with depth
- No dramatic change with seating
- Replication and generalization of results unknown

There are many exciting opportunities for future work

- Surrogate bones with better material properties
- New test bed for each installation
- Time series data rather than Frequency Response Functions
  - Obtain Holder (Lipschitz) exponent with wavelet analysis
  - Mimics operating procedures
- Implementation would require following Food and Drug Administration guidelines

Acknowledgements

- Vibrant Technologies
  - MEScopeVES experimental modal analysis software
- The Mathworks, Inc.
  - MATLAB numerical analysis software
- Hibbitt, Karlsson and Sorensen, Inc.
  - ABAQUS finite element software

Questions?