Stability of Implants in Total Knee Replacement Surgery

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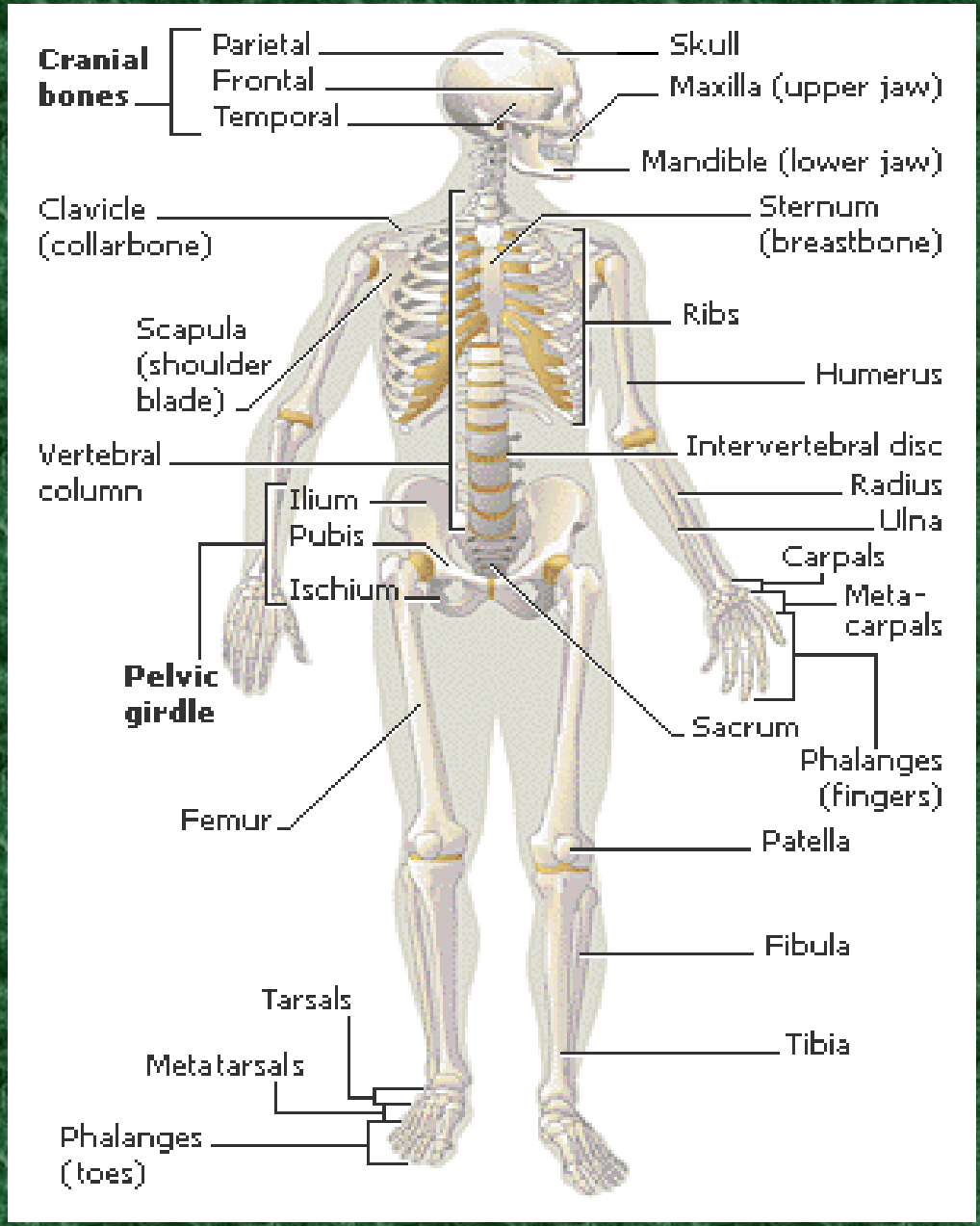
Bone from an Engineer's Perspective

Material Properties

- Anisotropic
- Heterogeneous
- Nonlinear
- Viscoelastic

Function

- **Mechanical**
  - **Support**
  - **Lever System**
  - **Protection**
- **Physiological**
  - **Hematopoiesis**
  - **Mineral Homeostasis**



http://encarta.msn.com/encnet/refpages

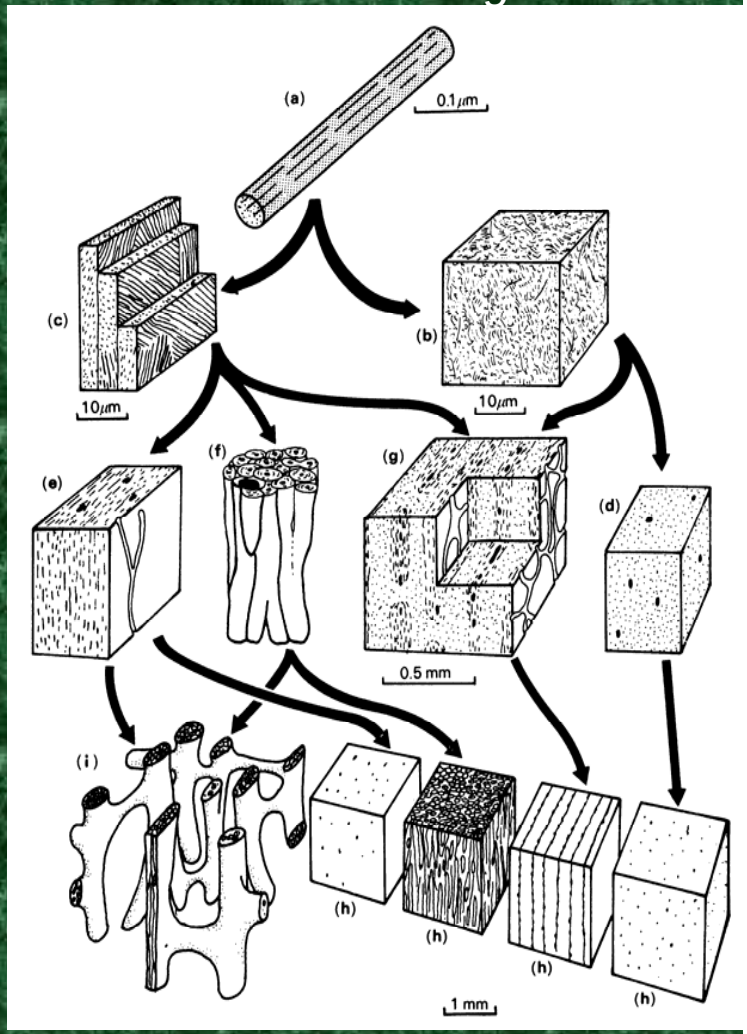
Structure

- Hierarchical
  - i.e., Composite material
- Constituents
  - Collagen
    - 1/3 of volume
    - 50% of dry weight
  - Proteins and glycoproteins
  - Calcium phosphate
  - Water

Hierarchical Structure

- **Lowest Level**
  - **Collagen Fibrils**
    - Arranged in parallel fashion
    - Give limited flexibility
  - **Crystals of calcium phosphate (hydroxyapatite)**
    - Surround and fill in between collagen
    - Give strength, hardness, and rigidity
- **Two Types of Bone**
  - **Cortical (compact)**
  - **Cancellous (spongy)**

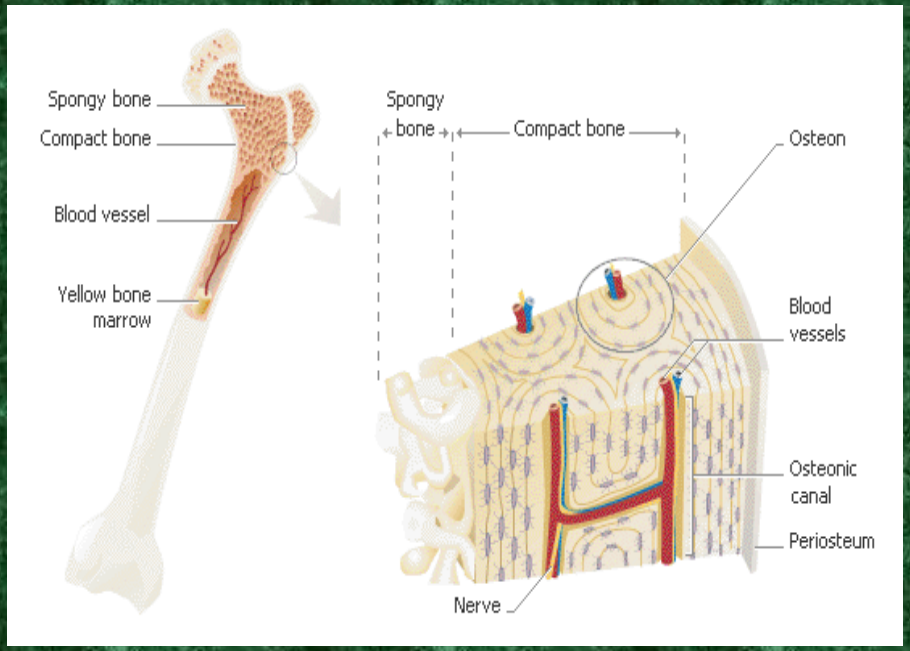
Wainwright 1982

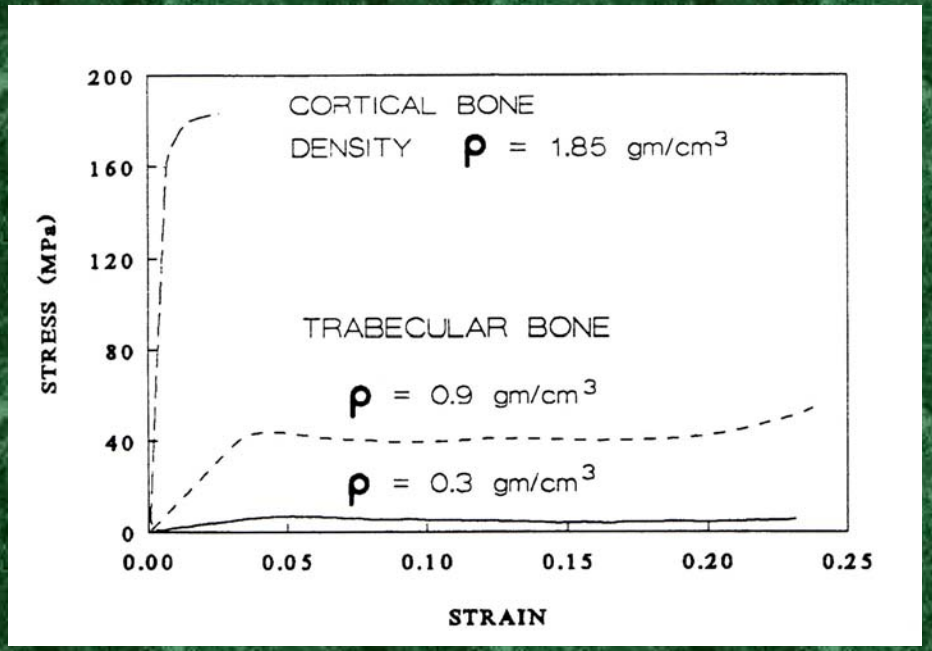


Cortical and Cancellous Bone

- Major physical difference between cortical and cancellous bone
  - Porosity

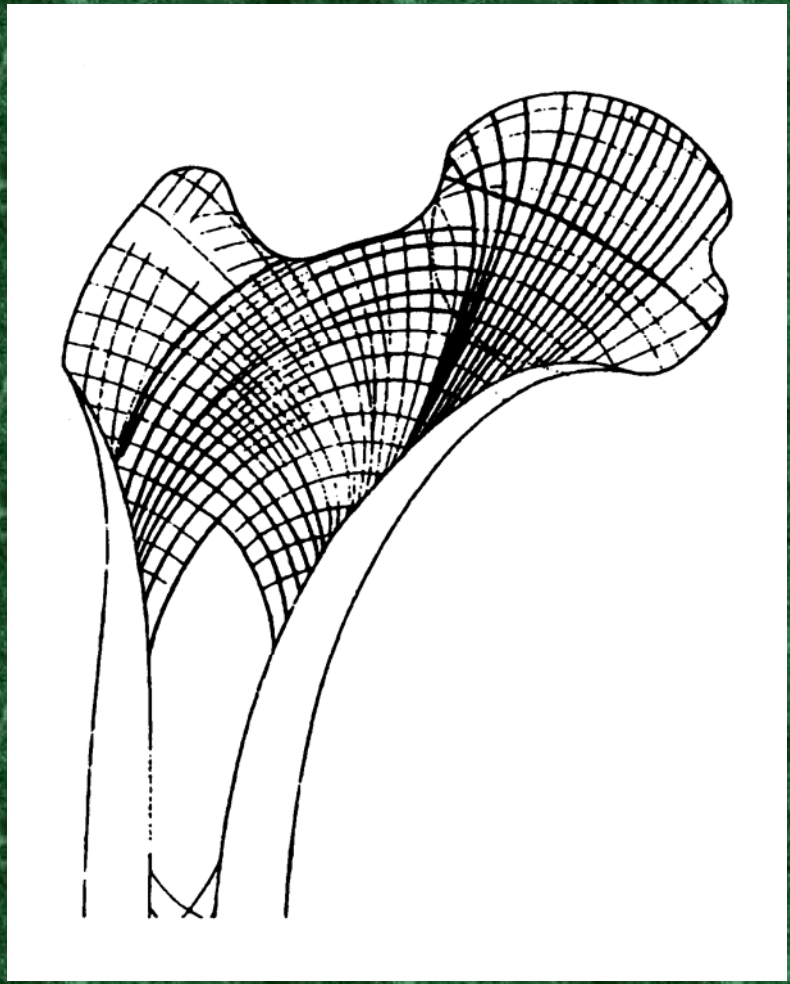
Mow 1997





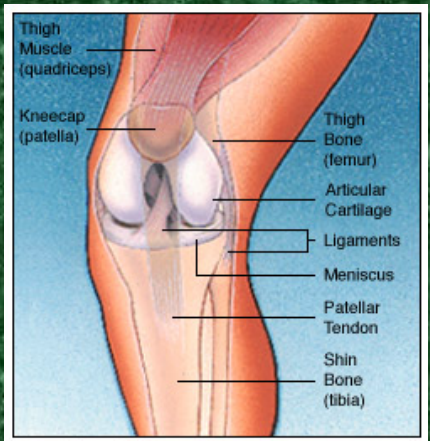
Bone Remodeling

- **Constantly remodeling itself**
- **Self-repairing**
- **Modifies structure based on load**
  - Dynamic loading more important than static loading

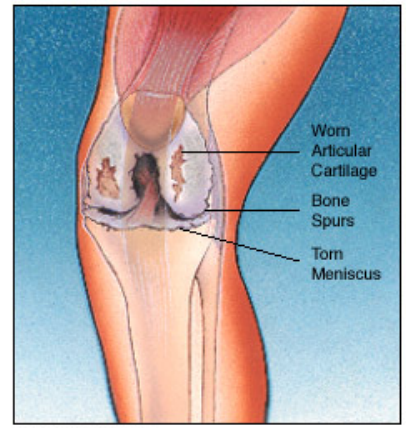


Total Knee Replacement (TKR)

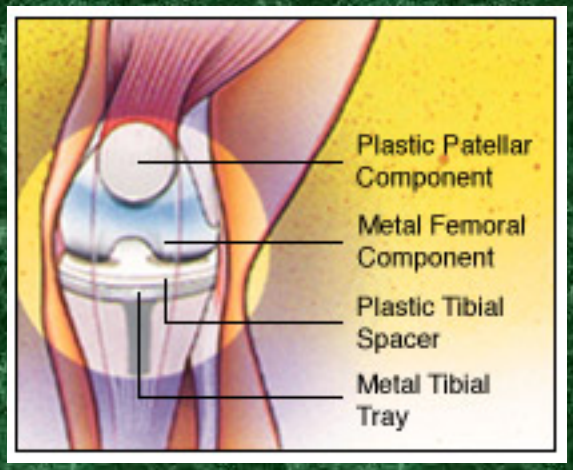
- Cartilage wears out or tears
  - Invasive surgery
- The components wear out
  - Revision surgery
    - Several years later
    - Cut more bone; lower tibial plateau



Normal Knee Anatomy



Knee with Arthritis

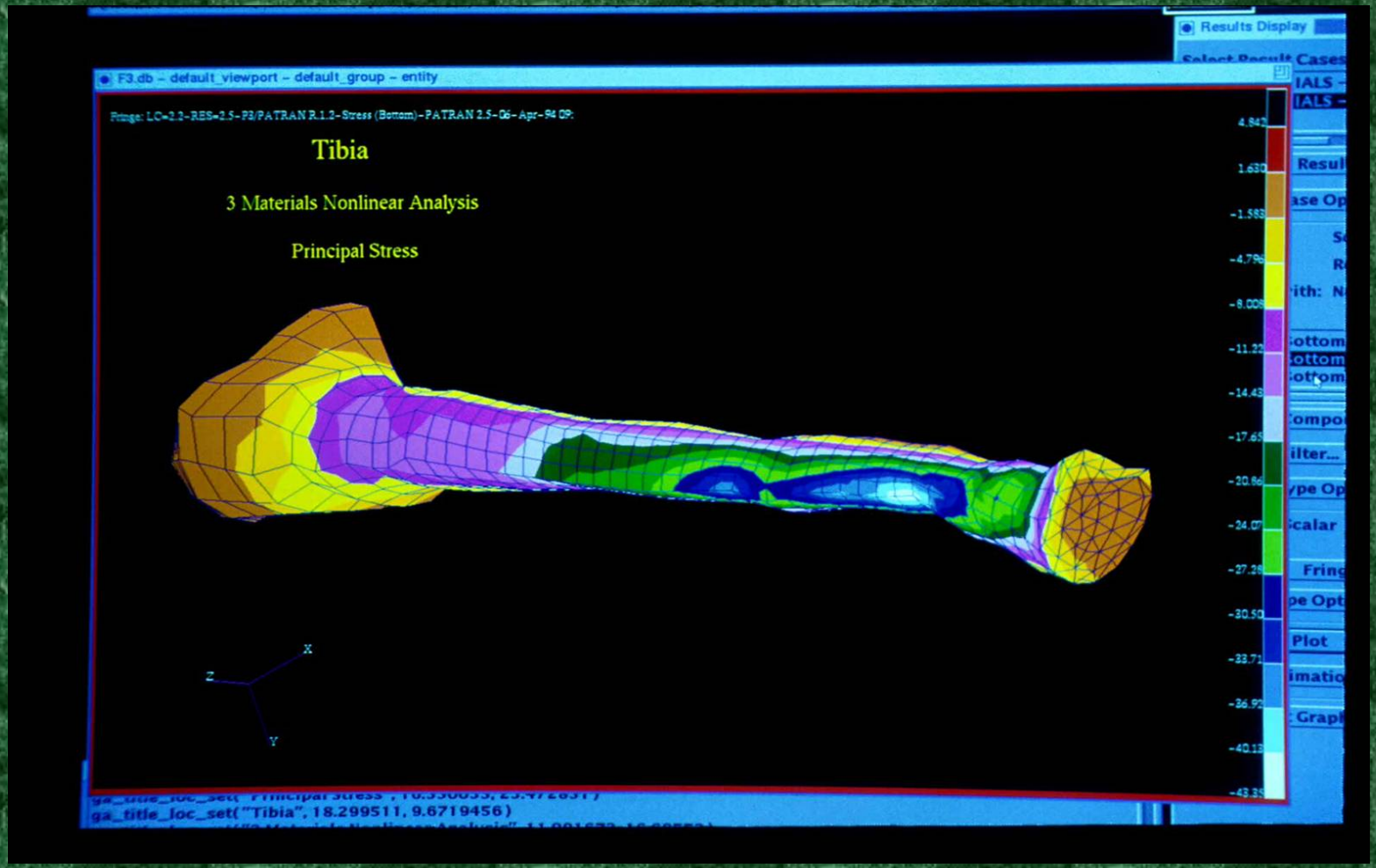


http://orthoinfo.aaos.org/booklet/thr_report.cfm?thread_id=9&topcategory=knee

Motivation for Study

- Scott & White collaboration with Dr. Christopher Chaput
- Find effect of implant's stem length on motion of the implant
- Find effect of removal of more bone at the tibial plateau on the motion of the implant
- Few studies on revision TKR

Tibial Stress Model



www.ent.ohiou.edu/~mehta/BIOMED/tibia_fea.htm

The Implants

- Type of implant
  - Stem
    - Length (40 mm, 80 mm, 155 mm)
  - No stem
- Fixation method
  - Cemented
  - Press fit

http://www.stryker.com/jointreplacements/sites/duracon/index.php

Goals

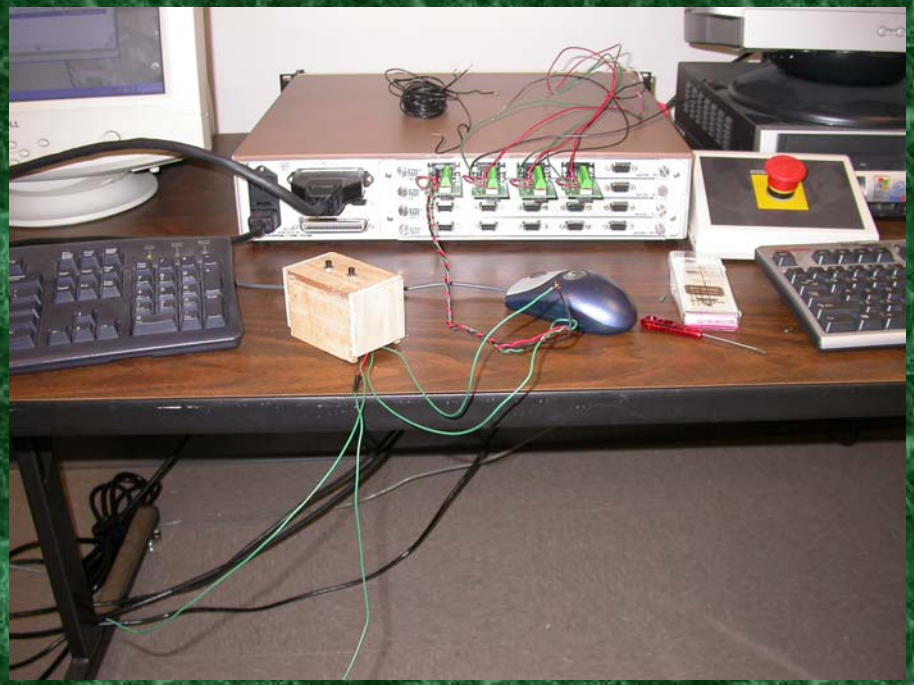
- **Compare stability of different implants based on their performance under compression in the following areas:**
  - **Vertical displacement**
  - **Horizontal displacement**
    - **Expected no greater than 400 microns (.4 mm)**
  - **Use geometry to determine micromotion of the center of the tibial plate**

Use of Synthetic Bones

- These bones mimic properties of real bone

Testing Machines

- MTS 858 Mini Bionix II
- Strain Smart
  - Synchronization Box



Testing Method

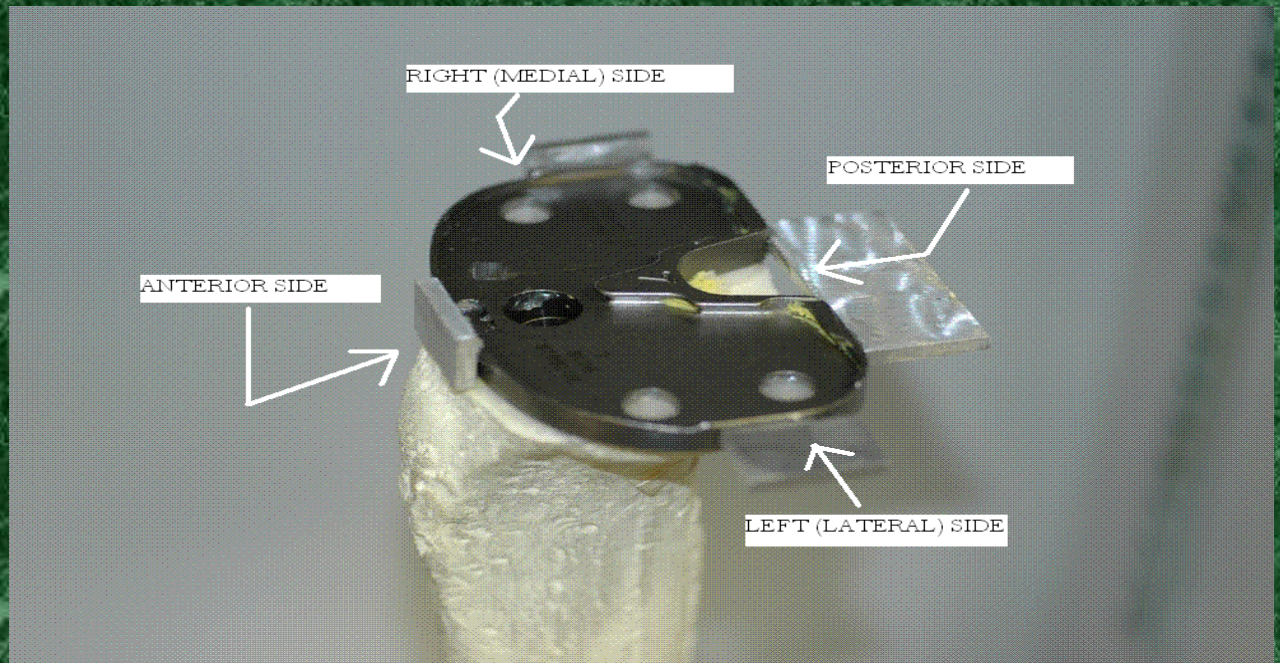
- Potting

Measuring Displacement

- LVDTs (linear variable displacement transducers)
- Measure the 3-dimensional displacement of implant
  - Anterior horizontal
  - Medial horizontal
  - Posterior vertical
  - Lateral vertical

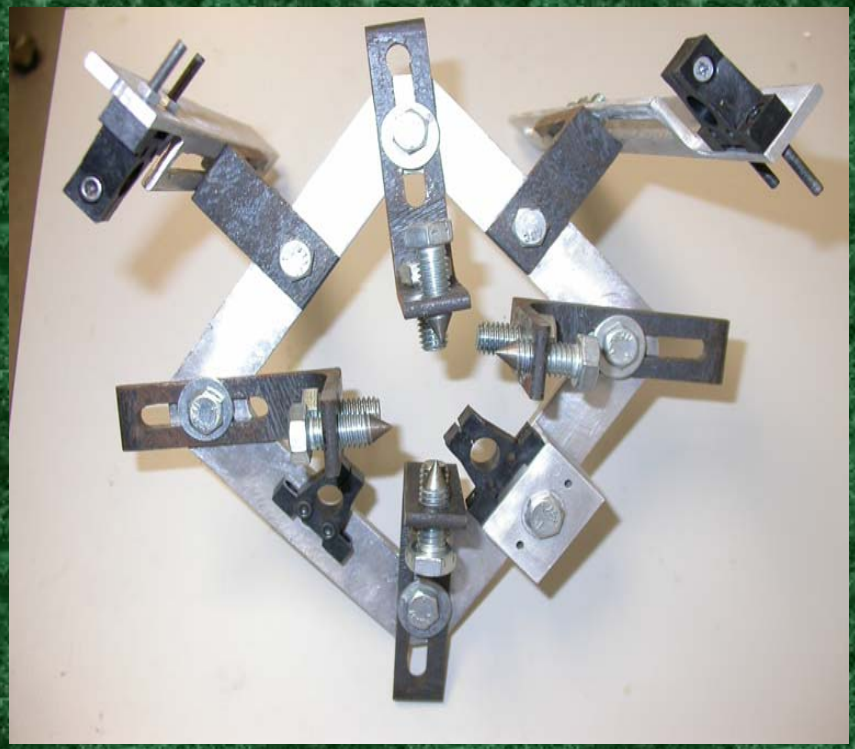
Interfacing Implant with LVDTs

- New extensions for the implant
- Glue to the top of the implant to which we would attach the extensions
- Epoxy extensions to the outside



Testing Method

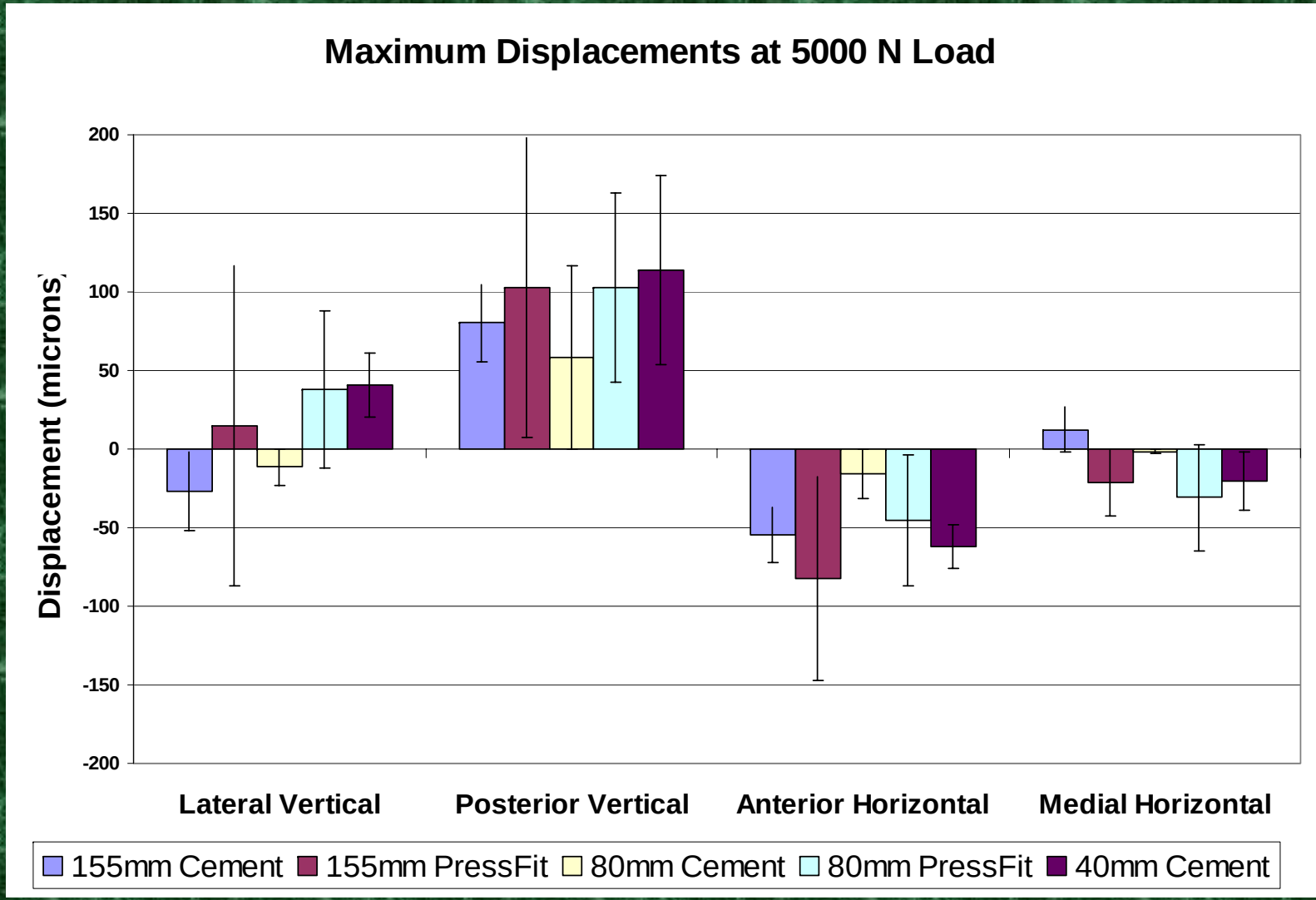
- **The Jig**



- **Loading at 3 degree angle**

Testing in Action

Graphical Results



Conclusions

- Trends
  - Shortest implant (40mm) has greatest motion
  - For same length, cemented implant moves less than press fit
- High variation in micromotion
  - Sample size too small for statistical significance
- In the process of more testing

Acknowledgements

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Questions?