Brain Model for Microelectrode Implantation Testing

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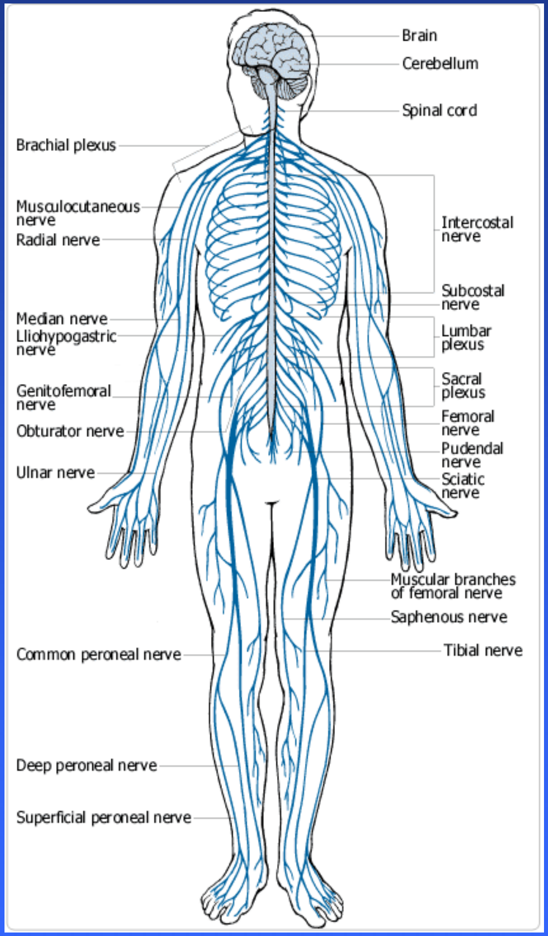
Neural Engineering

- What is neural engineering?
  - Combination of neuroscience, engineering, and clinical medicine
  - Characterize and manipulate neural tissue
  - Develop interfaces for sensory and motor systems
- Cortical sensory prosthetics is one division of neural engineering



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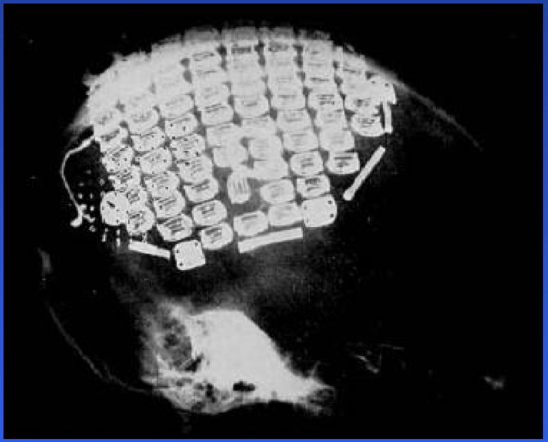
Cortical Sensory Prosthetics

- First experiments conducted in 1960's and 1970's

Electrical stimulation of visual cortex

Perception of phosphenes

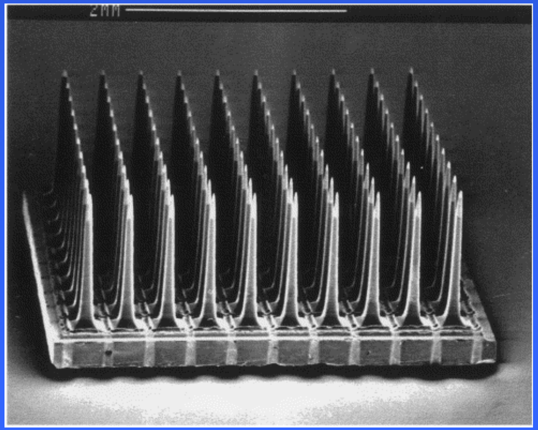


Brindley et al., 1968

- Developments

Electrical stimulation of cortical tissue

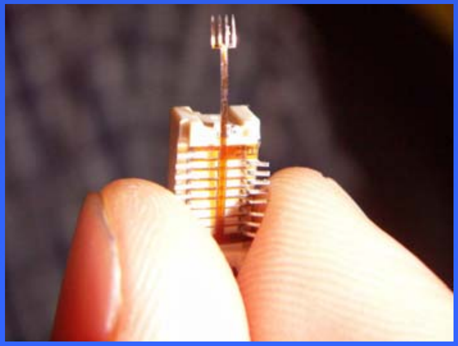
Sensory perception

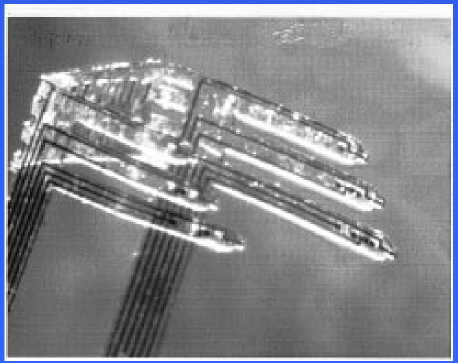


Normann et al., 1999

Microelectrode Stimulation of Auditory Cortex

- Cochlear implant cannot be used when nerves not intact
- Instead, implant directly into auditory cortex (Heschl's gyrus)
- Polyimide-based intracortical electrode array
  - Flexible
  - Biocompatible
  - Coated with PGA

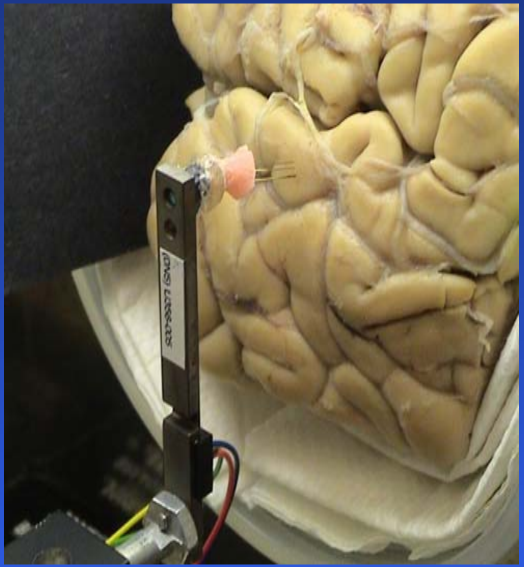




Rousche et al., 1999

Problem

- Implant micromechanical testing is done to determine ideal microelectrode structure
- Current models are not sufficient
  - Human cadaver brains
  - Rat brains
- Better model of human brain is needed for mechanical implantation testing

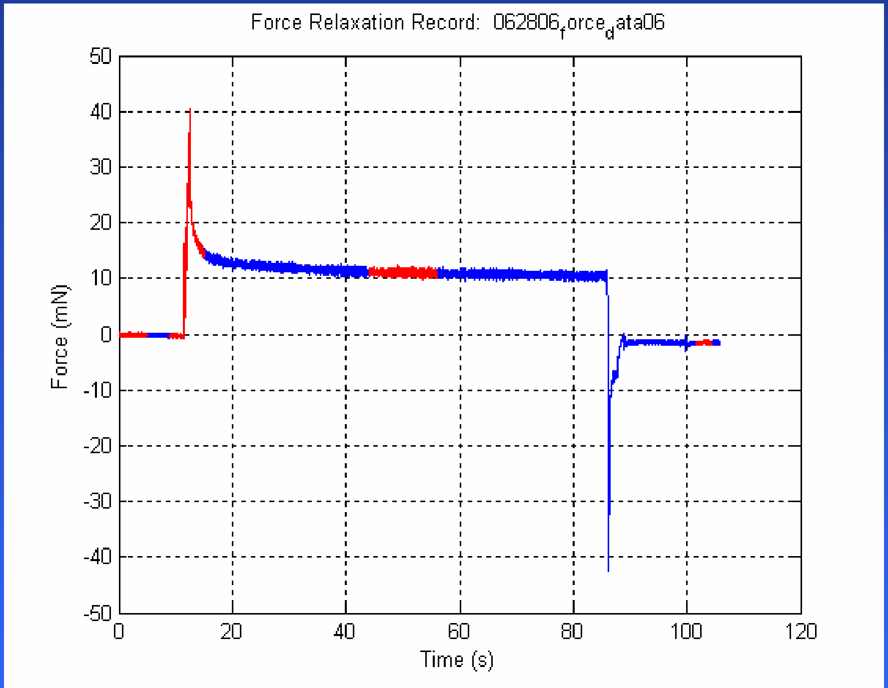


Solution

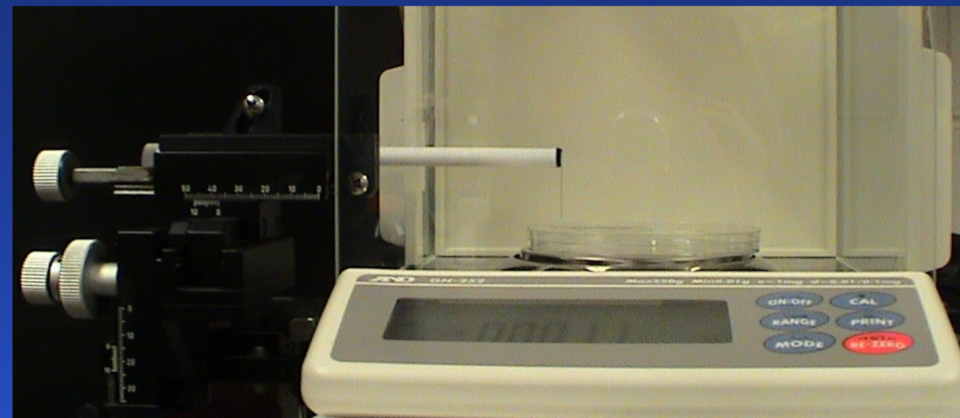
- Brain Model
  - Anatomy
  - Mechanical Properties
  - Radial pressure variations
  - Protocol
- Experimentation
  - Techniques for inserting flexible device
  - Measure insertion forces before and after PGA coating

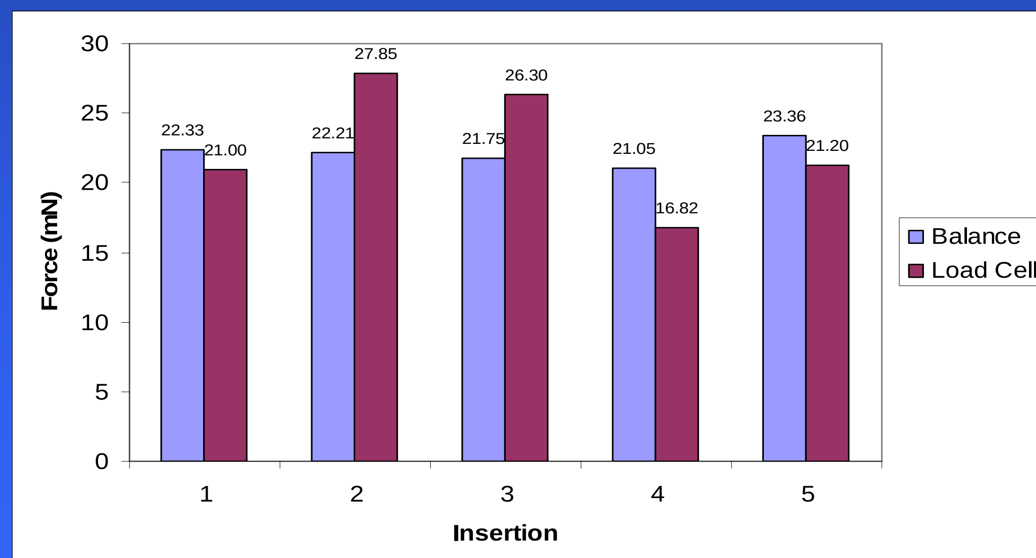
Force Testing

- To find percentage of agar gel that most closely matches mechanical properties of live brain tissue and pia membrane
- Compare agar gel to cadaver brain tissue and literature data



Force Acquisition Systems

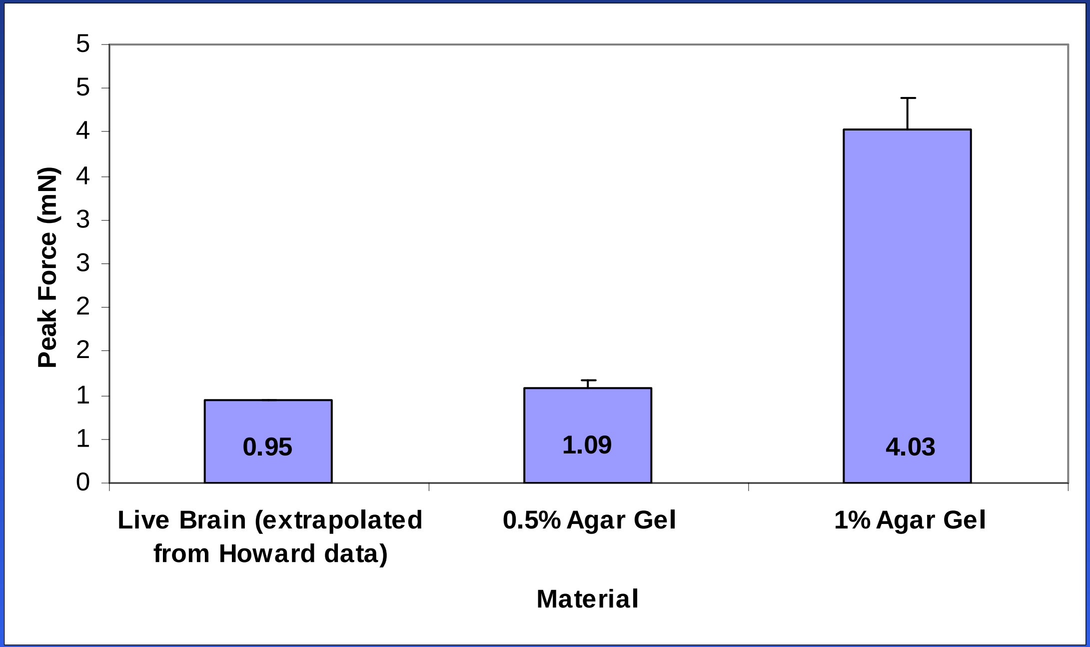




Peak forces for five separate microelectrode wire insertions into 5% agar gel at various insertion speeds, locations, and depths as measured by the balance force acquisition system and the load cell force acquisition system simultaneously

- 2.2% overall increase from balance force measurement to load cell force measurement

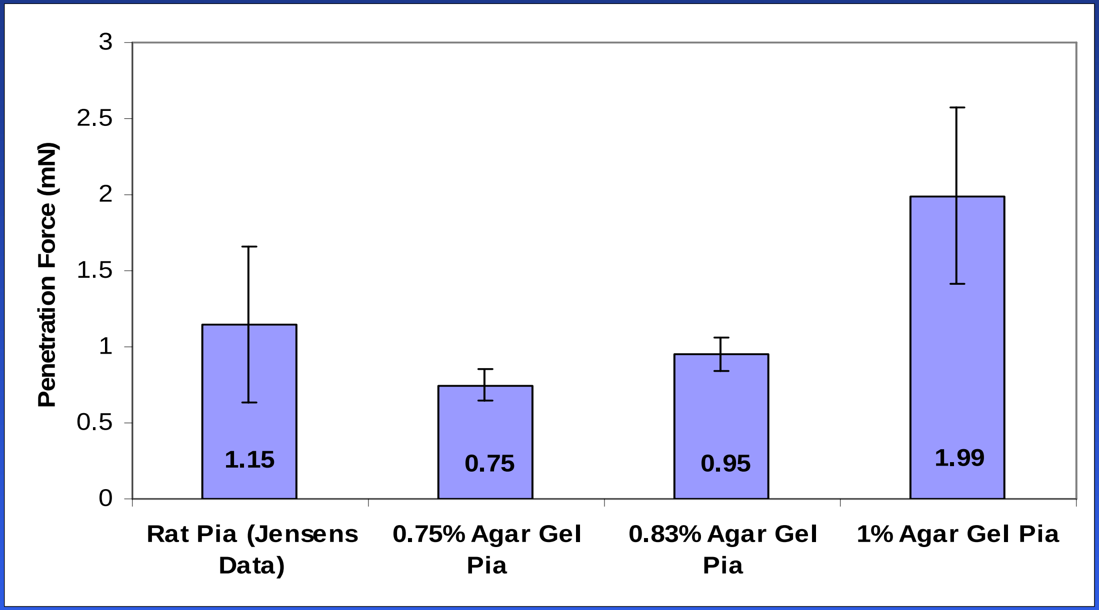
Force Testing: Matching Live Brain Tissue



Peak force associated with inserting microelectrode wire 2 cm at approximately 0.33 mm/s into 0.5% and 1% agar gel for comparison to peak force extrapolated from Howard (1999) data

- Howard et al. (1999) inserted probe into live human brain
- 0.5% agar gel has mechanical properties similar to live brain tissue

Force Testing: Matching Pia Membrane



Penetration force associated with inserting microelectrode wire 2 mm at approximately 2 mm/s into 0.75%, 0.83%, and 1% agar gel pia membranes for comparison to penetration force associated with inserting microelectrode through rat pia membrane (Jensens data)

- Jensen et al. (1999) inserted microelectrode through rat pia membrane
- 0.83% agar gel has mechanical properties similar to rat pia membrane

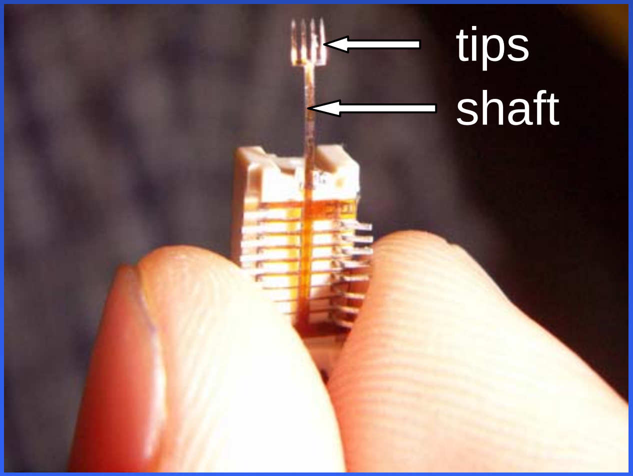
Brain Model

- Plaster mold of model brain
- 0.5% agar gel for brain tissue
- 0.83% agar gel for pia membrane
- Fissures and Heschl's gyrus incorporated into model for more realistic anatomy

Techniques for Microelectrode Insertion

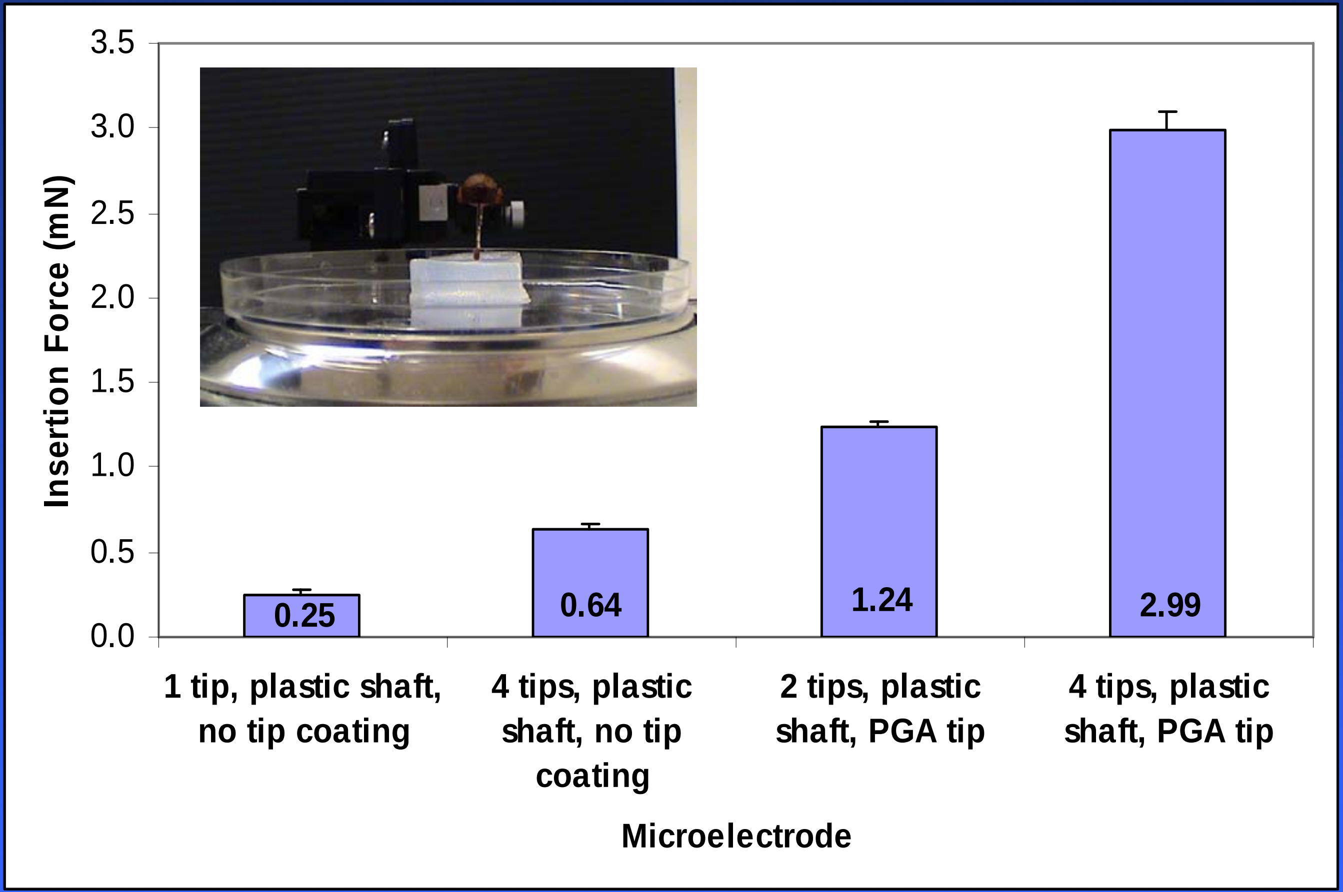
- Flexible polyimide-based microelectrode
- Five categories for Implantation Testing

1) No coating
2) PGA coating on tip
3) PGA coating on tip and shaft
4) Plastic coating on shaft
5) PGA coating on tip and plastic coating on shaft

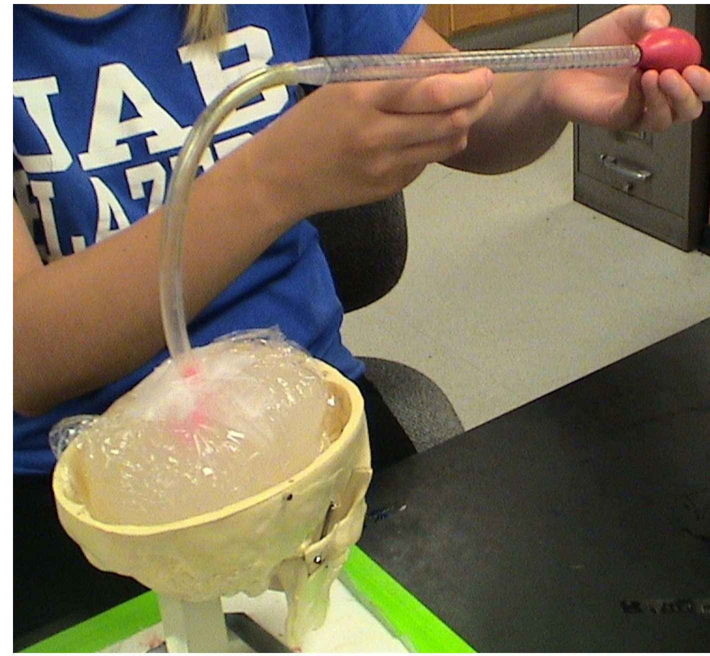


Insertion Force Testing

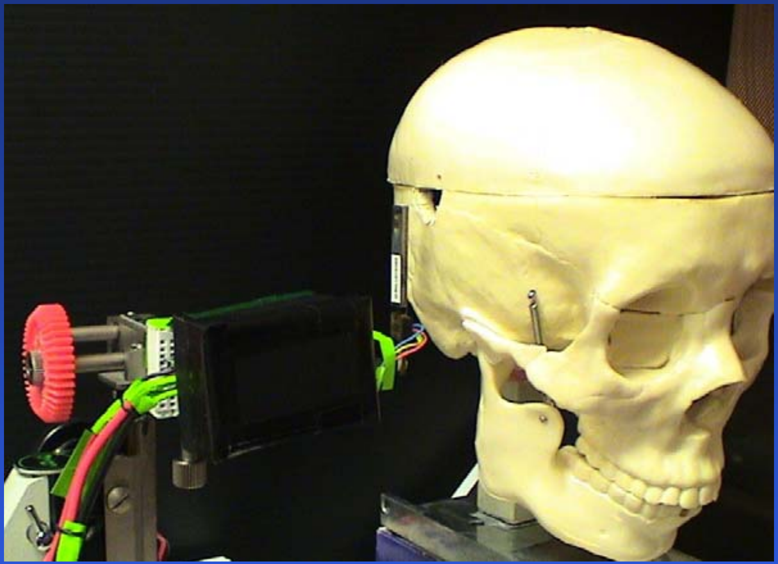
- Only have microelectrodes intended for use in rats
- Microelectrodes with no coating buckle
- Microelectrodes with no tip coating curve within gel
- Microelectrodes with plastic shaft + PGA coating on tip implant vertically



Insertion force associated with inserting polyimide-based microelectrodes with different coatings 2 mm into 0.5% agar gel at 2 mm/s



Brain Model in Skull



- Brain model in skull to simulate surgical procedure in humans
- Implant life-size microelectrodes into Heschl's gyrus of model brain
- Measure insertion forces for microelectrodes with new load cell
- Chronic oscillatory testing with microelectrodes in skull possible

Conclusions

- 0.5% agar gel mechanically models live human brain tissue
- 0.83% agar gel mechanically models pia membrane
- Polyimide-based microelectrode with plastic lining on the shaft and PGA coating on the tip is promising
- Brain model can be used to test microelectrode insertion forces and may aid in developing better device design

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