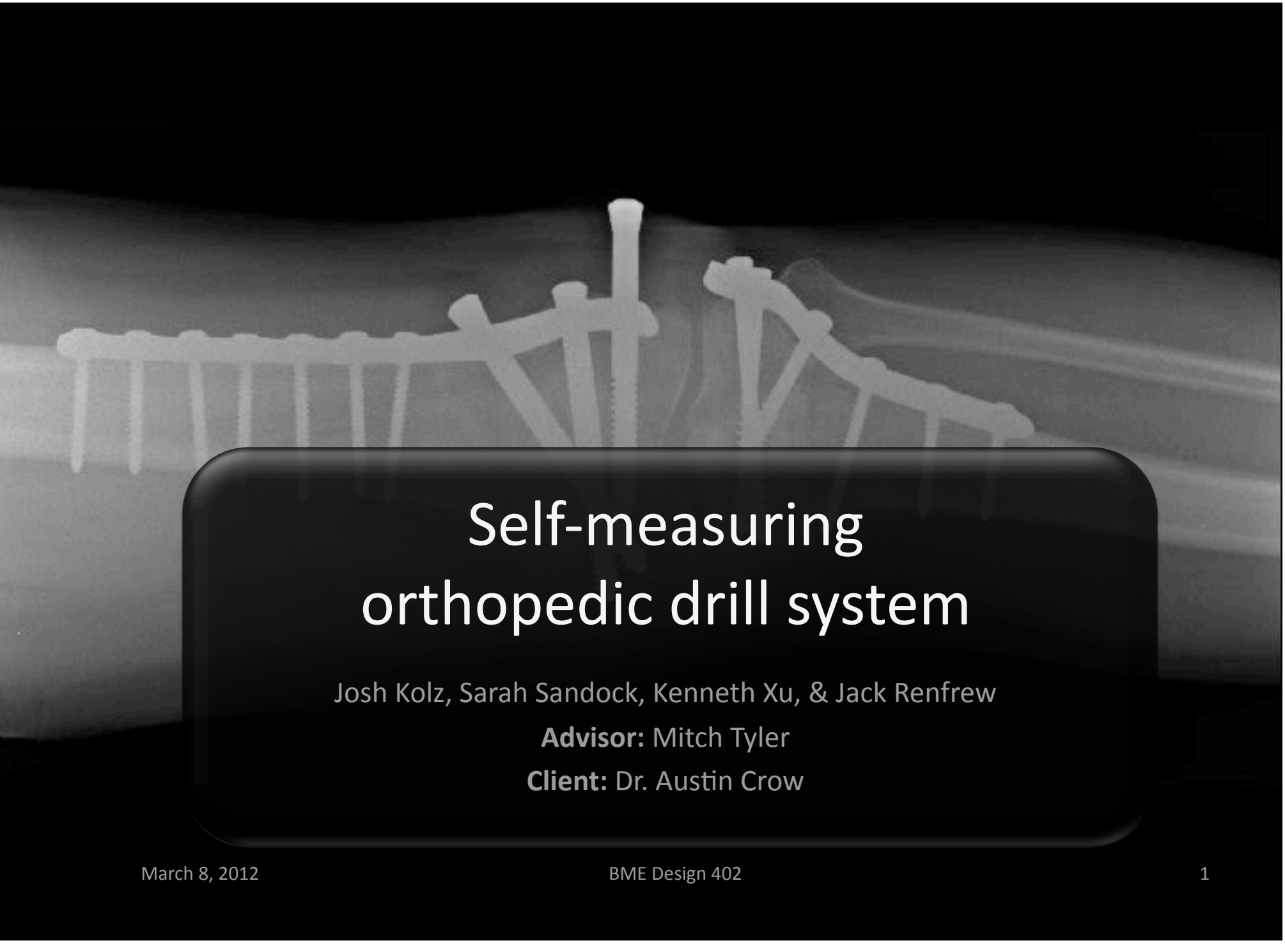


Self-measuring orthopedic drill system

Josh Kolz, Sarah Sandock, Kenneth Xu, & Jack Renfrew

Advisor: Mitch Tyler

Client: Dr. Austin Crow

Agenda

- Background
- Our device
- Fluid design
- Modeling
- Testing
- Conclusions

Surgery

- Orthopedic surgery drills
- Plunging
- Measure depth
- Screw & plate placement

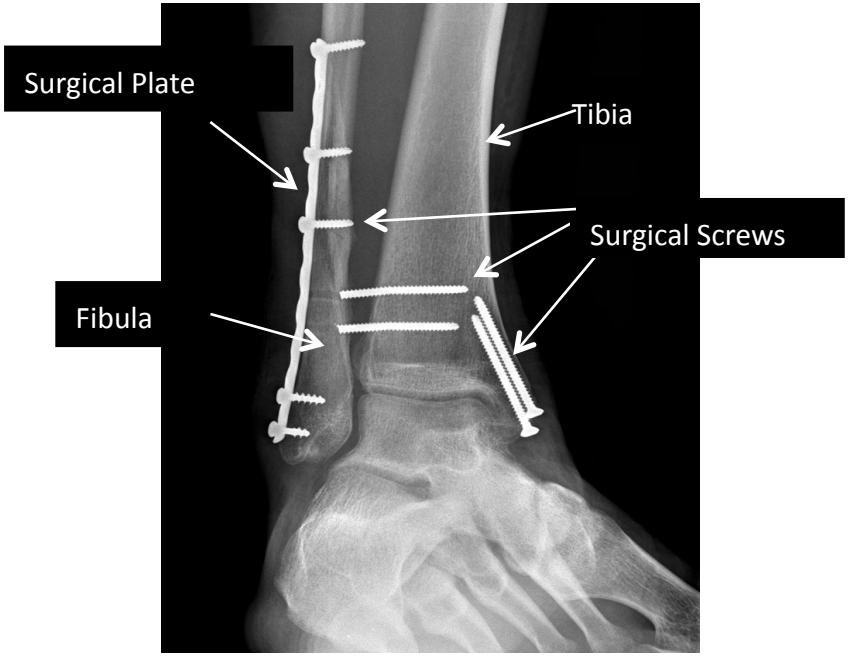


Figure 1: X-ray of orthopedic screws and plate in a fibula and tibia [1]

Tools

Figure 2: Orthopedic screws and plate [2]

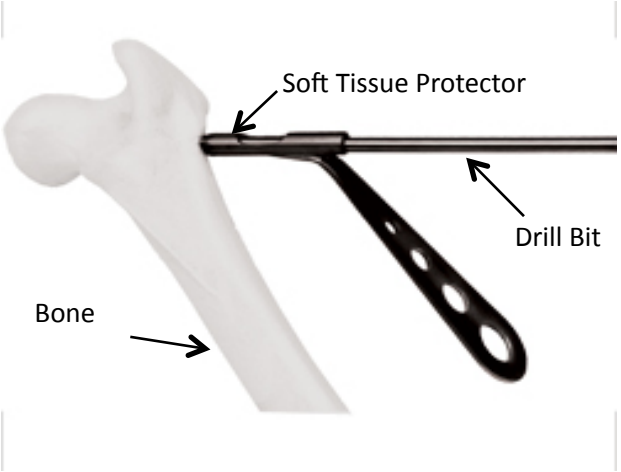


Figure 3: Tissue protector on long bone [3]

Figure 4: Depth gauge client currently uses

Current Practice

Figure 4: Depth gauge client currently uses

a)

b)

Figure 5: Depth gauge a) before use and b) during measurement

Anatomy of Bone

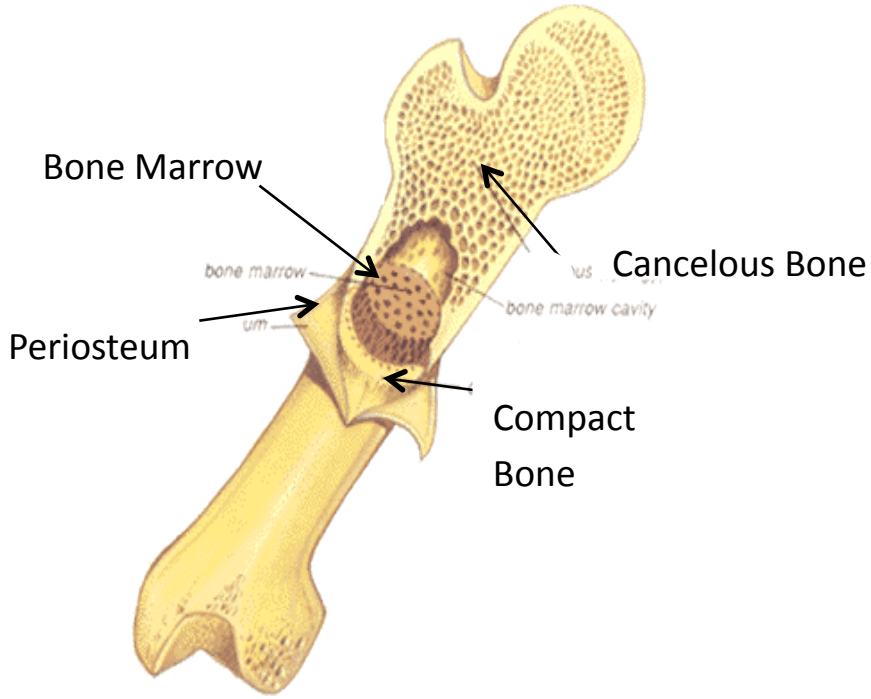


Figure 6: Layered bone model [4]

Major Bone Layers

- Compact bone
- Spongy bone
- Bone marrow

Motivation

- Eliminate mechanical depth gauge
- Decrease plunging
- Decrease surgical time

Design Criteria

- Accurate detection of depth (+/- 2mm)
- Reduce plunging magnitude (+/-2mm)
- Integrate into a soft tissue protector
- Made using autoclavable material
- Does not compromise drill use or surgeon's vision

Previous Design

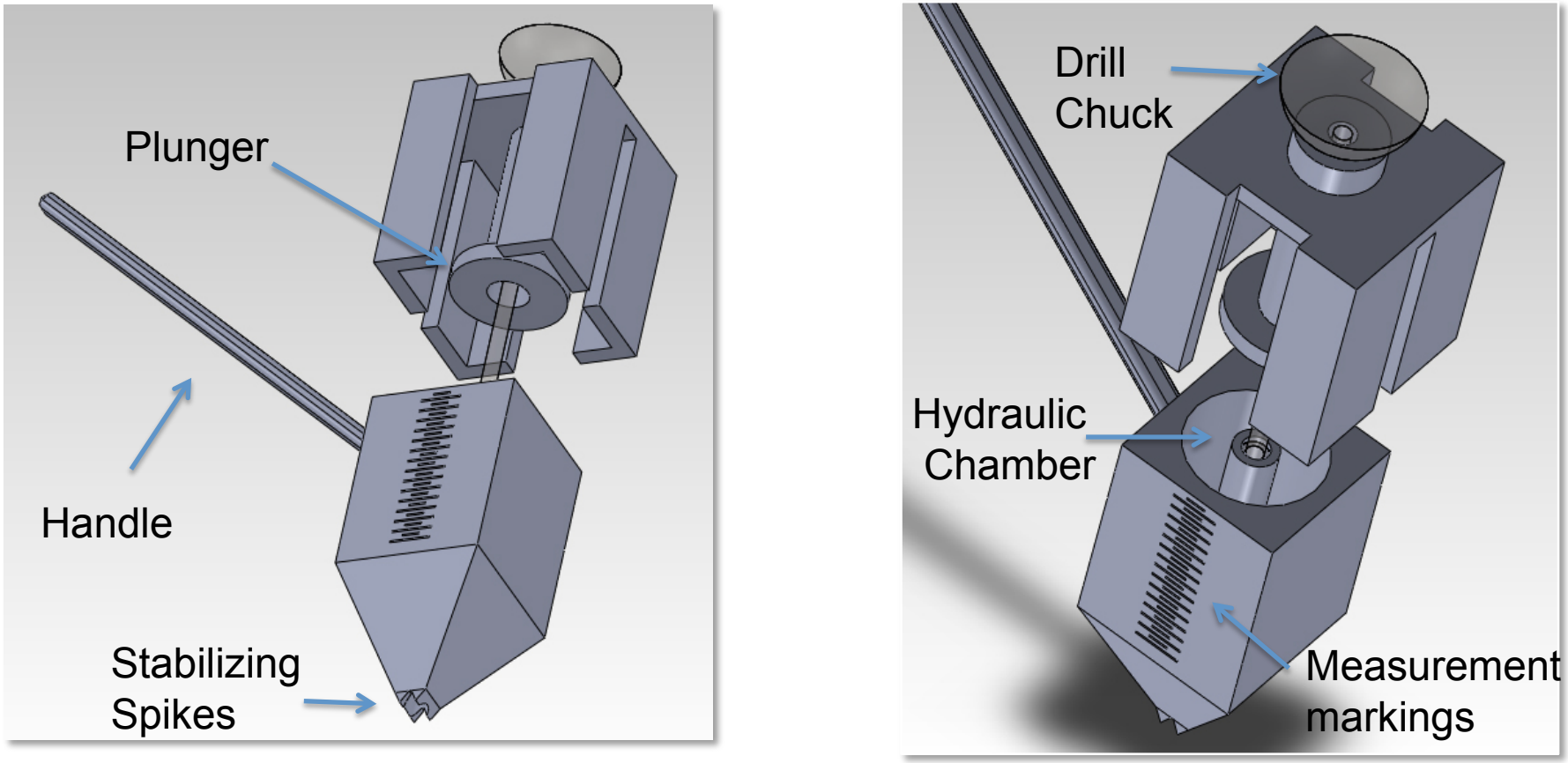


Figure 7: Hydraulic slider V6 in SolidWorks.

Current Design

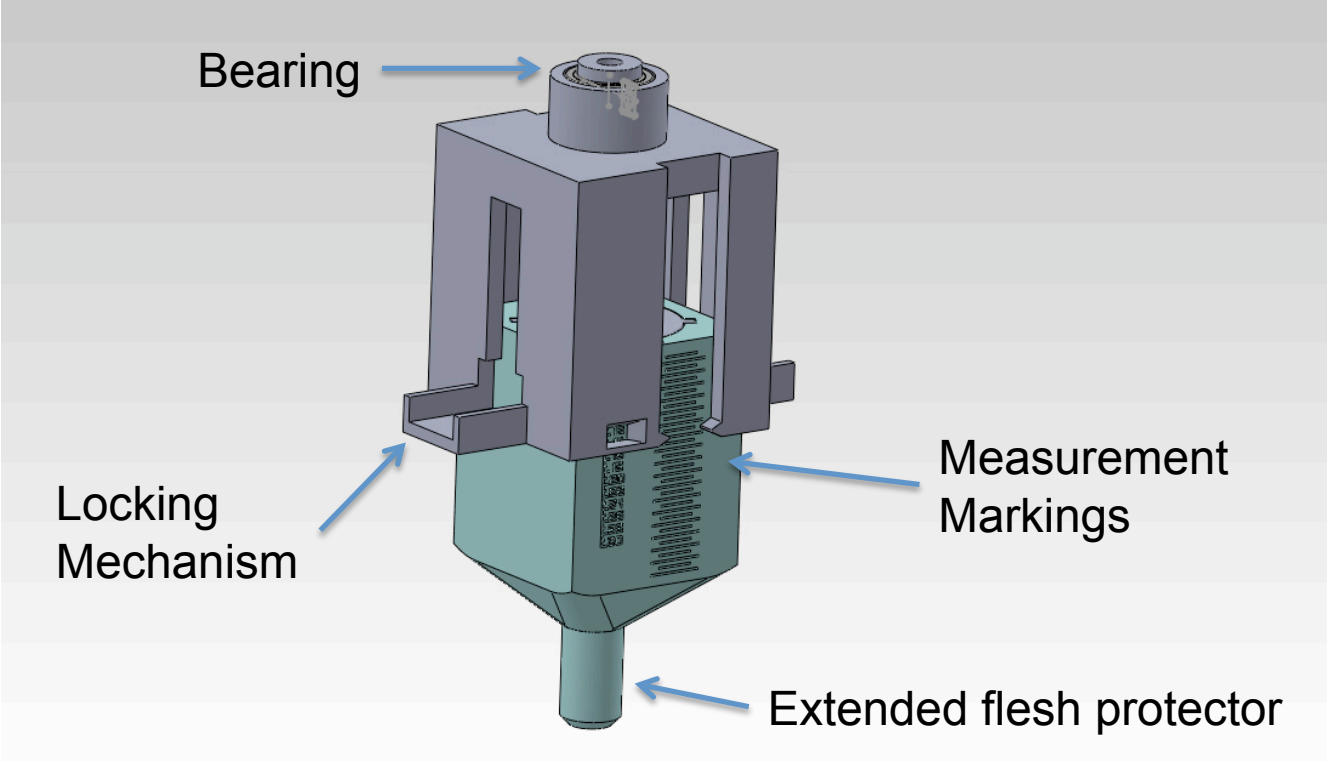


Figure 8: Hydraulic slider V7 in SolidWorks.

Ideal Fluid

- Dilatant Non-newtonian fluid

- Advantages
  - Exhibits shear thickening behavior
  - More reactive force to reduce plunge

- Disadvantages
  - Previous testing with corn starch solution showed phase separation over time
  - Requires constant mixing or electrostatic stabilization to prevent sedimentation

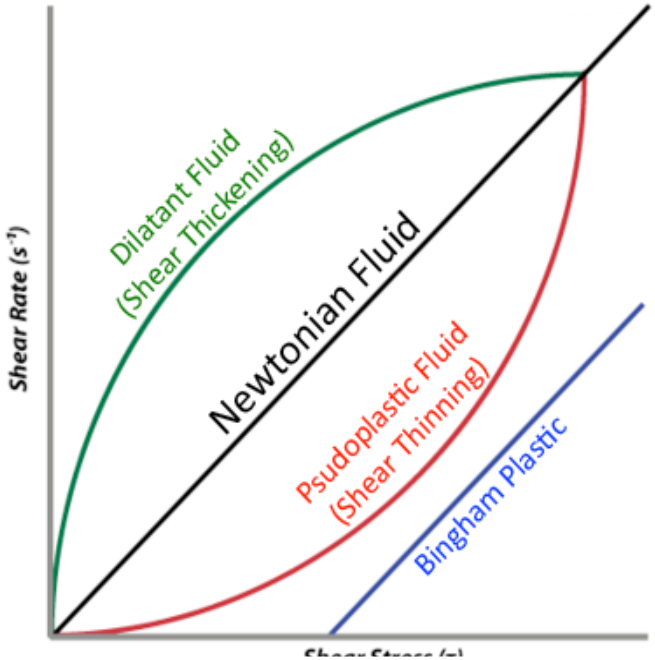
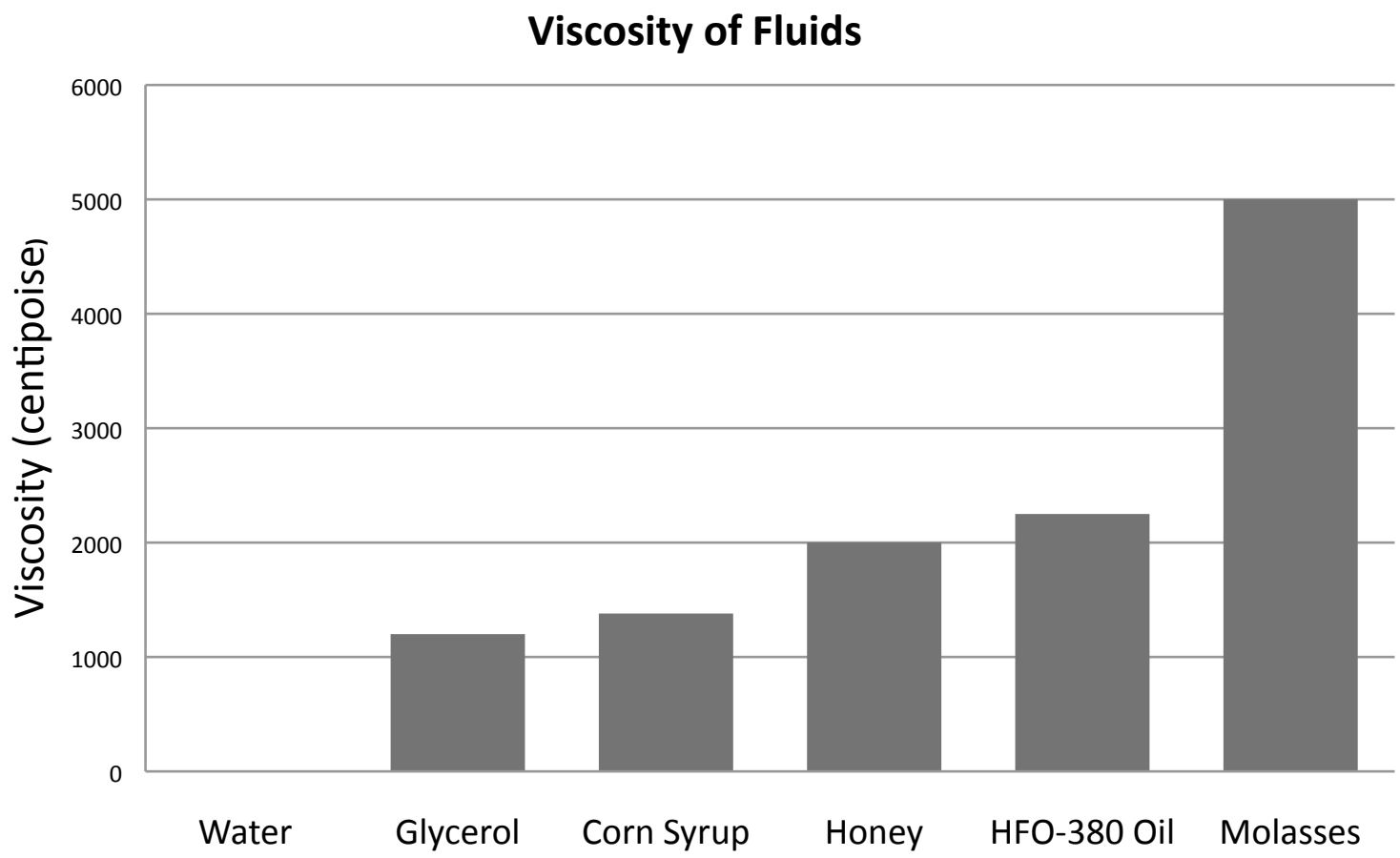


Figure 9: Reactions of various fluids to an increase in shear (x-axis) [6].

Common Viscous Fluids



Practical Fluid

- Glycerol (propane-1,2,3-triol) is the current selection for the “hydraulic fluid”
- Has uses in botanical extracts, pharmaceutics, antifreeze, hygiene products
- It is a metabolite (backbone of triglycerides)
- Newtonian fluid with a viscosity of 1200 centipoise (1.2 Pa-s) at 20°C
- Readily available and cheap
- Possible flaws: viscosity changes drastically with an increase in temperature
- Possible alternatives: fuel oil, newtonian fluids, honey

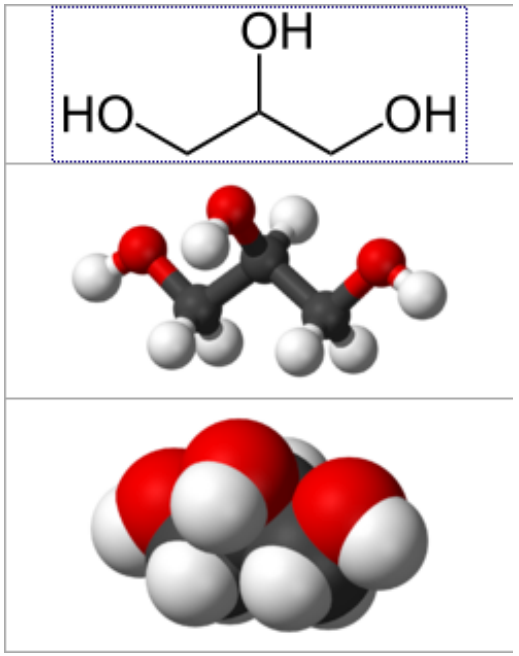


Figure 9: Glycerol backbone and space filling models.

Fluid Flow Modeling

- What is Fluid Flow modeling?
  - Using the prototype design (solidworks)
  - Run simulations with a “hydraulic fluid”

- Why is this important?
  - Monitor physical properties
  - Change fluid properties
  - Change prototype design

Procedure

1. Determine geometries
2. Determine fluid space
3. Set simulation conditions
4. Determine fluid properties
5. Run simulation & analyze

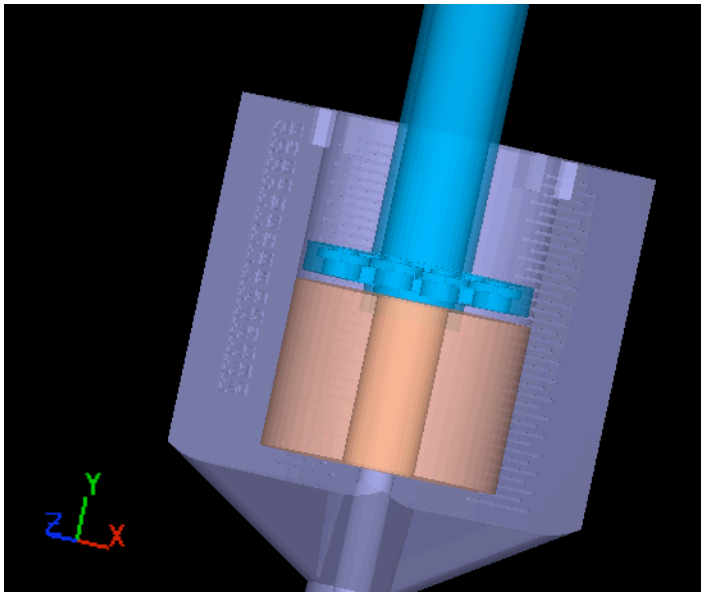


Figure 10: Creating aligned device geometries and fluid space (peach) in flow 3D program with a focus on the conditions of the plunger (blue)

Conditions

- Previous Testing:
  - F_C - Minimal force to drill through bone (V_C)
  - F_D - Total drilling force (force plate testing)
- Assumptions:
  - When plunging F_D is seen by plunger
  - F_D is opposed by the forces:
    - $F_u(t)$ – Force of user realizing plunging
    - $F_F(t)$ – Force of the plunger/fluid
  - F_U is zero with no user adjustment
- Find $F_F(t)$ for:
  - Ideal non-Newtonian fluid
  - Viscous Newtonian fluid

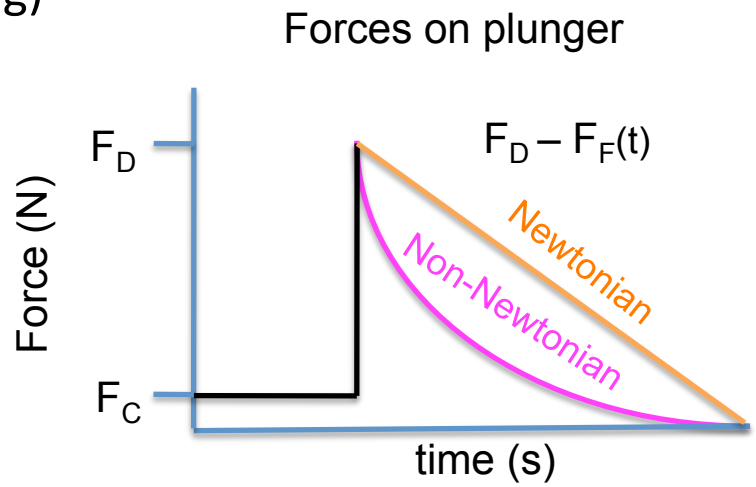


Figure 11: Force seen by plunger in drilling trials with Newtonian and non-Newtonian "hydraulic fluids"

Simulation videos

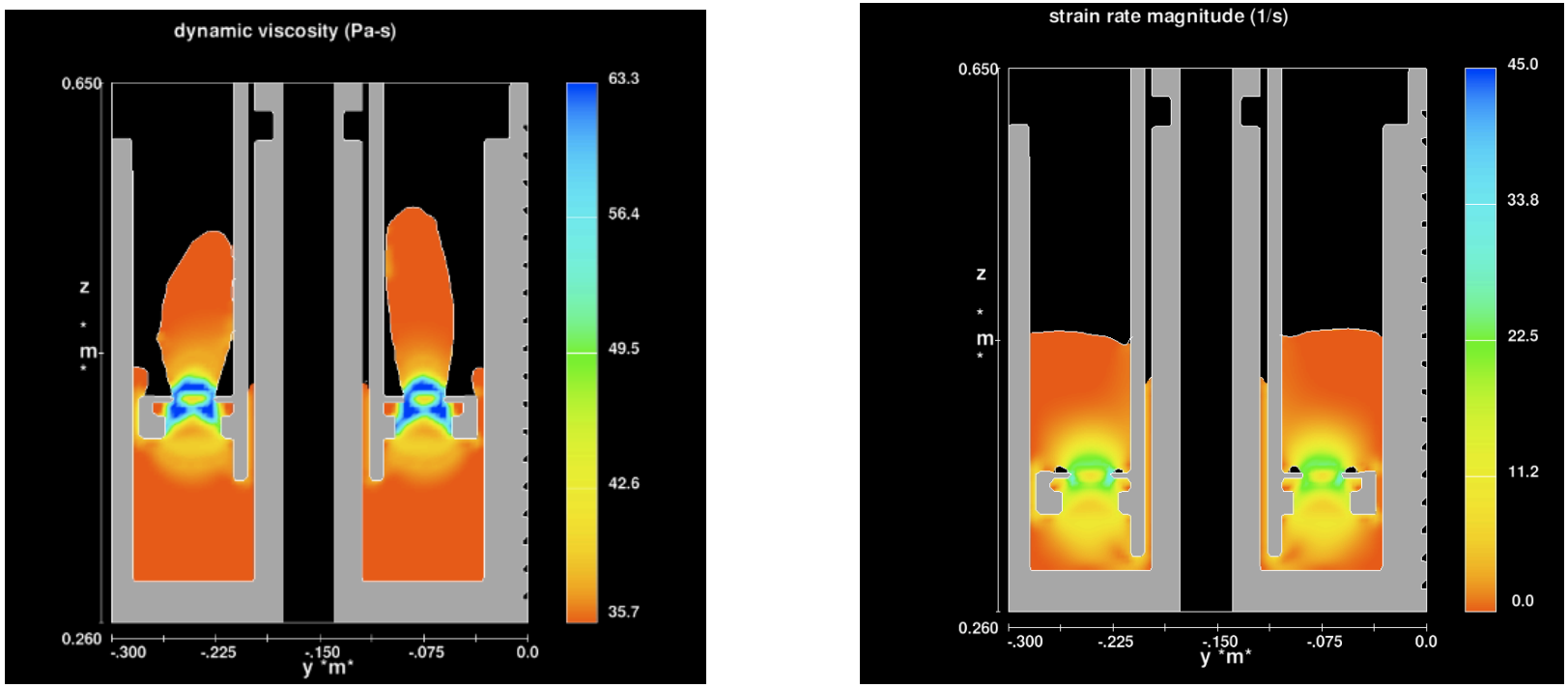


Figure 12: Video simulations using device geometries, a viscous fluid, constant velocity showing (left) dynamic viscosity and (right) strain rate magnitude during plunging

Future

- Collect data needed to model
  - glycerol (Newtonian)
  - Ideal non-Newtonian fluid
- Expectations
  - Practical fluid reaction will be similar to ideal fluid
  - Sufficient force can be generated to halt drill progression

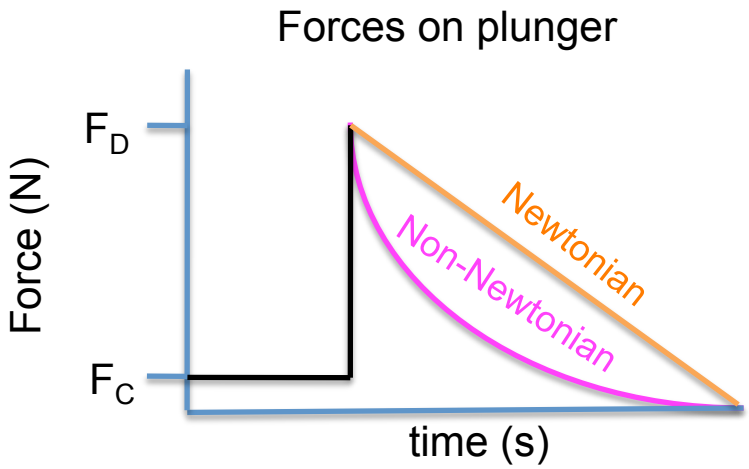


Figure 11: Force seen by plunger in drilling trials with Newtonian and non-Newtonian "hydraulic fluids

Plunging Measurements

- Drill through bone
  - Chicken (wrist and small bones)
  - Bovine (long bone)
- Measure plunge into meat
- Determine measurement accuracy
- Expectations
  - Minimize plunge
  - Less deviation

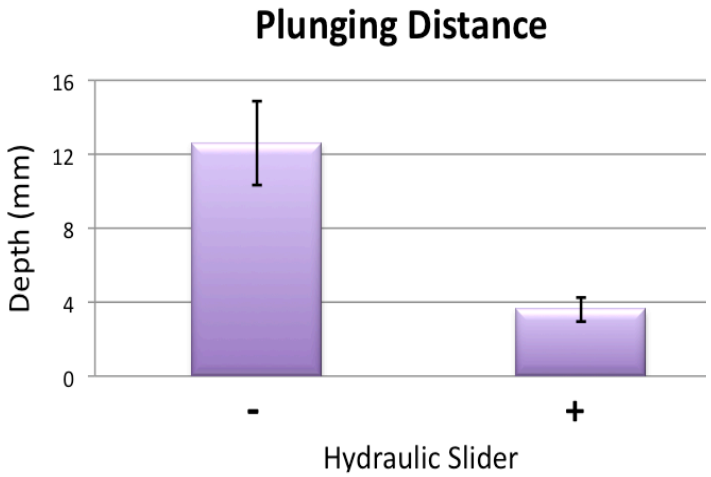


Figure 13: Testing results of plunging with and without drill-stop device with honey as "hydraulic" fluid

Future Work

- Metal Fabrication
  - Stainless steel
  - Decreased tolerances
  - Currently out of budget
- Testing
  - ABS prototype
  - Stainless steel prototype
  - Temperature testing
- Outreach

Figure 14: Precision machining [5]

Acknowledgements

Dr. Austin Crow

miniValve

Flow3D

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Pictures

[0] title slide - http://0.tqn.com/d/orthopedics/1/0/w/1/pilonpostop.jpg

[1] http://www.silverfishlongboarding.com/forum/longboard-videos-photos/67128-silverfish-hall-meat-58.html

[2] http://img.diytrade.com/cdimg/125566/8070293/0/1235444712/Wire_and_Pin_Drill.jpg

[3] http://www.veterinary-instrumentation.co.uk/images/P/412.jpg

[4] http://staff.tuhsd.k12.az.us/gfoster/standard/bone1.gif

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