Self-measuring orthopedic drill system

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Background: Surgery

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

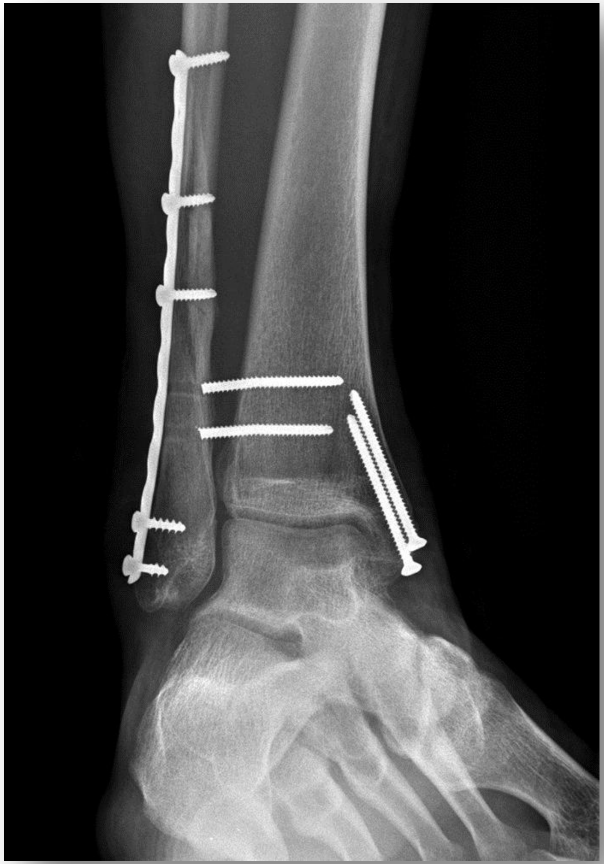


Figure 1. Orthopedic screws and plate [1]

Background: Tools

Figure 2. Orthopedic screws and plate [2]

Figure 3. Tissue protector on long bone [3]

Figure 4. Depth gauge client currently uses

Background: Current Practice

Figure 4. Depth preceptor client currently uses

a)

b)

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

Background: Layers of Bone

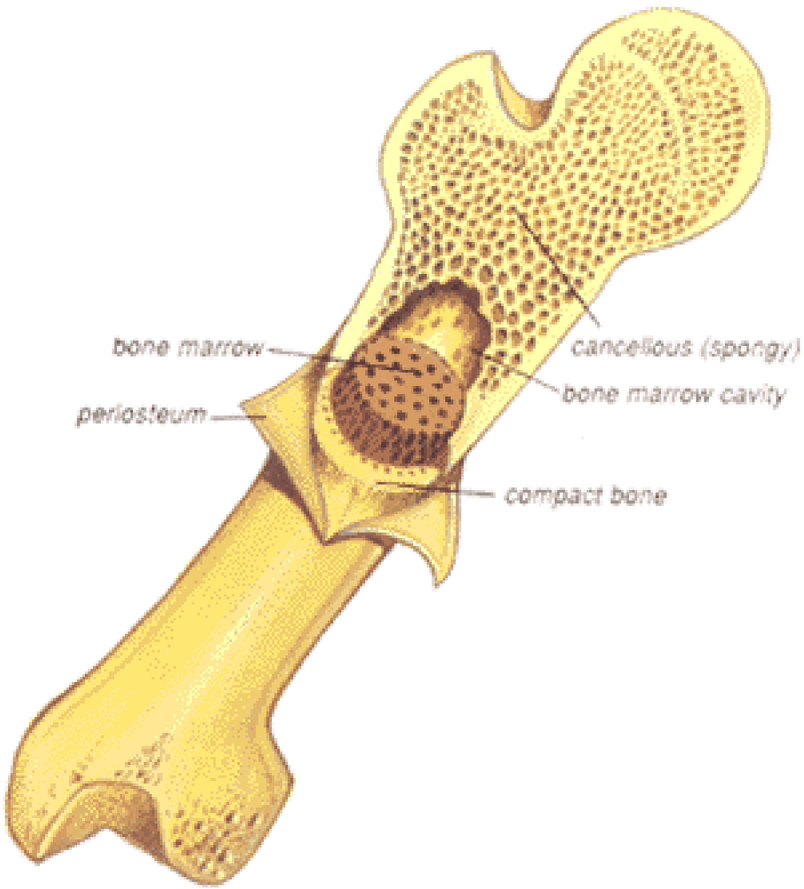


Figure 6 Layered bone model[4]

Major Bone Layers

- Compact bone
- Spongy bone
- Bone marrow

Motivation

- Cutout mechanical depth guage
- Decrease plunging
- Decrease surgical time

Design Criteria

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

Design Alternatives

Mechanical


Figure 7. Hydraulic pump [5]


Figure 8. Mechanical slider [6]


Figure 9. Interlocking gears [7]

Electrical

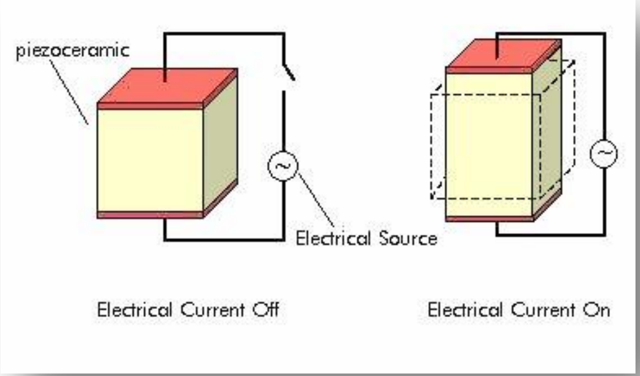


Figure 10. Piezoelectric material [8]


Figure 11. Velocity profiling [9]

DA: Slider

- Slider mechanism attached to the soft tissue protector
- Two sliders
  - First slider zeros
  - Second slider measures

Figure 12. Slide rule design [10]

✓ Gives a precise measurement of bone depth

✗ Inaccurate measurements due to plunging

DA: Interlocking gears

- Gear interlocked with grooves in drill bit
- As gear is moved, it turns a mechanical counter which measures depth

Figure 13. Lap counter [11]

✓ Gives a precise measurement of bone depth

✓ Gives a digital readout of depth

✗ Inaccurate measurements due to plunging

✗ Friction between gears and drill bit would cause wear

✗ Small gears would be hard to manufacture

DA: Hydraulics

- Uses a non-newtonian fluid to prevent plunging
- Viscosity of fluid increases exponentially with an increase in stress

$$\eta = K\dot{\gamma}^{n-1}$$

η = viscosity
K = material-based constant
γ̇ = applied shear rate

Dilatant behavior occurs when n is greater than 1

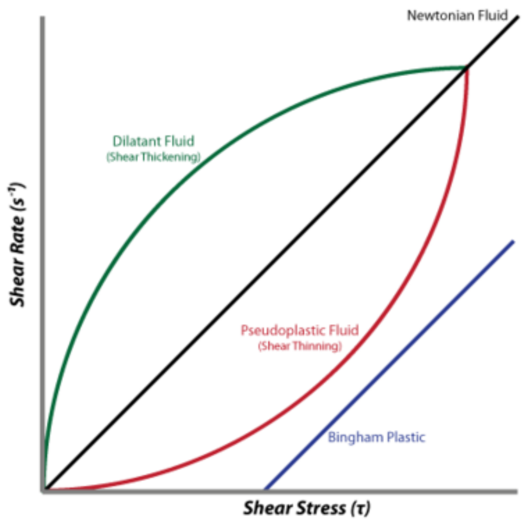


Figure 14. As stress increases, shear rate decreases exponentially causing a thickening of the dilatant fluid. [12]

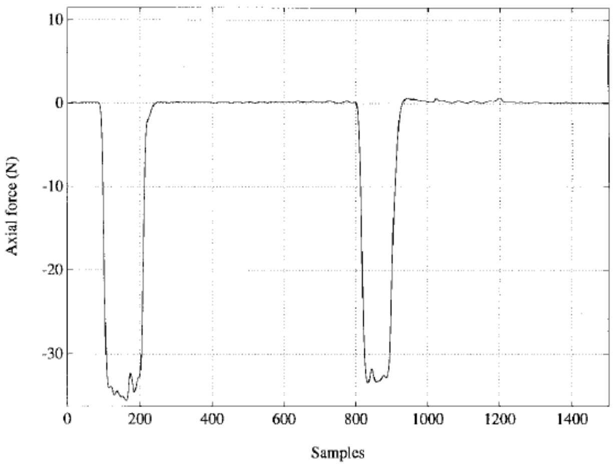
✓ Reduces plunging making measurements more accurate

✗ Difficult to maintain initial properties of the material.

DA: Piezoelectric Sensor

- Piezoelectric sensor converts axial force measurement to voltage
- Voltage processed by a microcontroller
- Suppresses plunge by feedback control to drill motor

✓ Versatility (programmable)
✓ Surpasses resolution requirements
✓ No external modifications to the drill
✗ Algorithm Development
✗ Design Difficulties
✗ Extensive Hardware Implementation



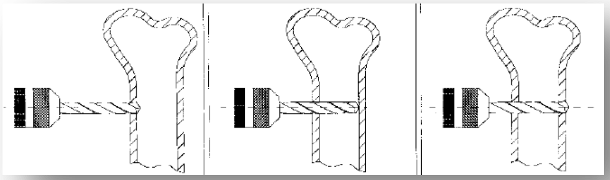
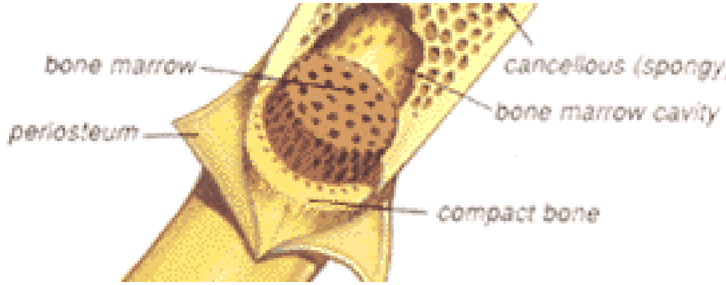


Figure 15. Axial force while drilling through long bone [13]

DA: Velocity profiling

- Velocity profiling will develop characteristic patterns
- Monitor velocity via magnetic flux
- Assuming:
  - constant force on the drill
  - constant cutting rate/rotation
- Logic feedback control over motor



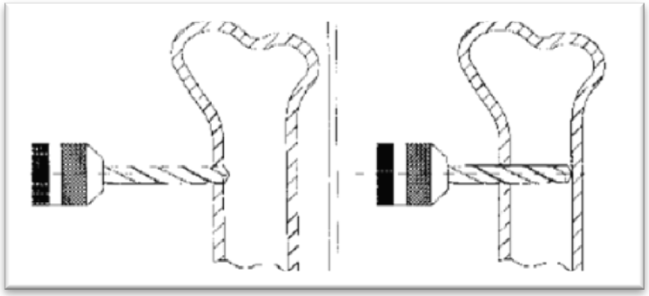


Figure 16. Drilling through long bone [13]

✓ Versatility (programmable)
✓ Surpasses resolution requirements

✗ Design Difficulties
✗ Extensive Hardware Implementation

Design Matrix

Table 1. Design Matrix

	Prevent Plunging (30)	Accurate Measure (30)	Manurafact-urable (10)	Feasible (10)	Client Input (20)	Total
Hydraulic	24	15	10	10	20	79
Slider	8	25	10	10	20	73
Cog	8	25	7	10	15	65
Piezo	28	10	2	3	5	48
Mag	28	30	5	2	10	75

Final Design: Hydraulic Slider

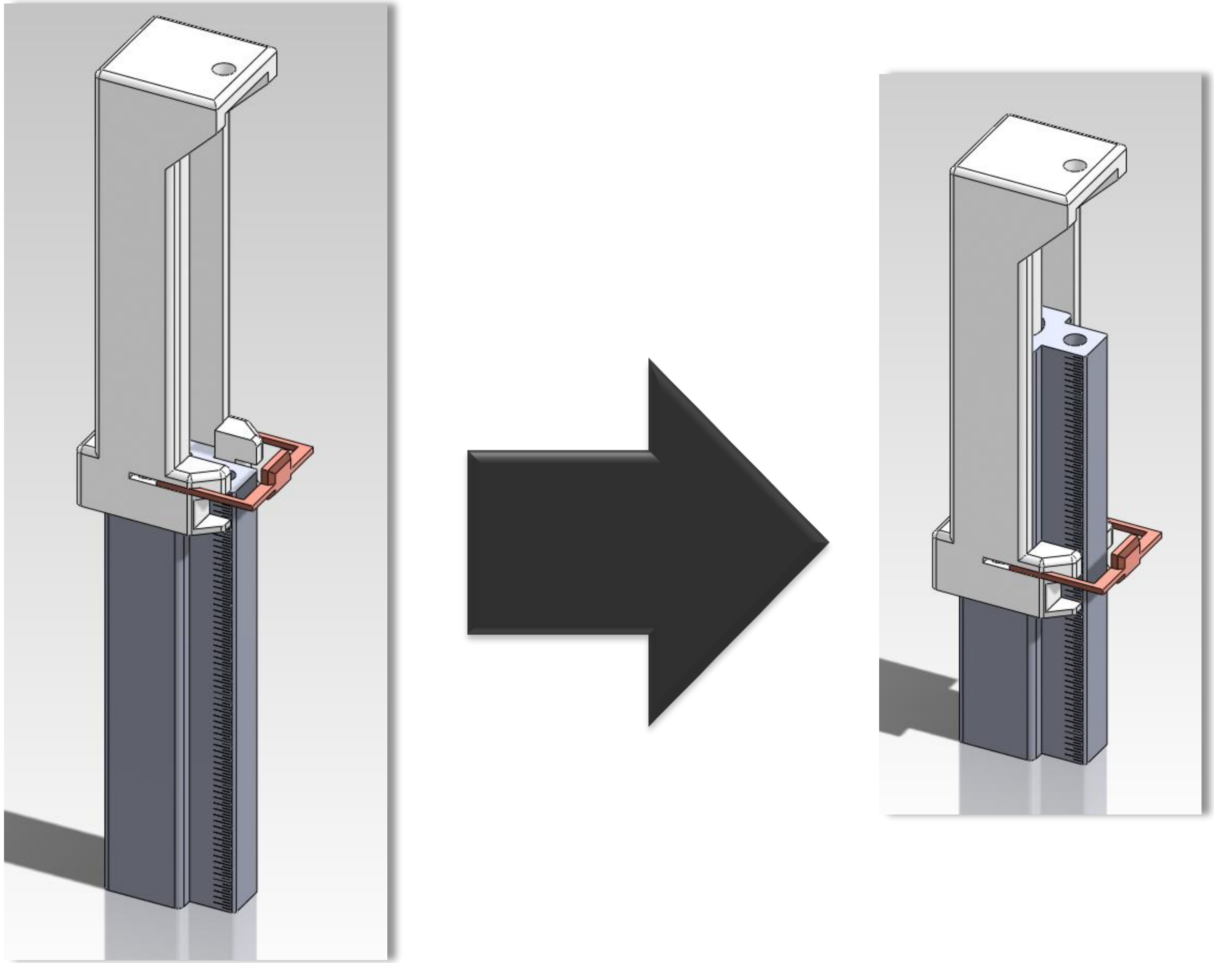


Figure 17. Our hydraulic design (solidworks) in positions: a) fully extended and b) mid-drilling

Final Design: Hydraulic Slider v2.0

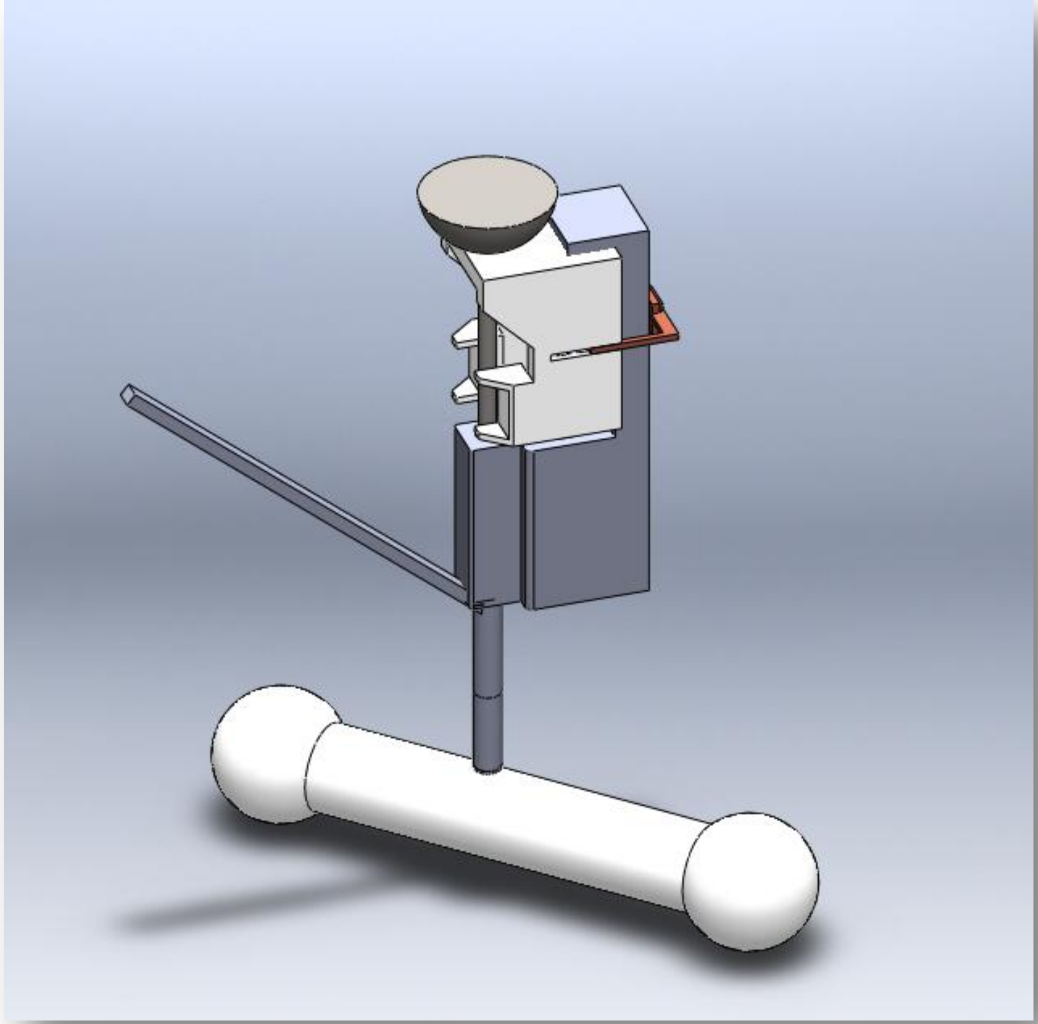


Figure 18. Our hydraulic design (solidworks) v2.0

Final Design: Hydraulic Slider v2.0

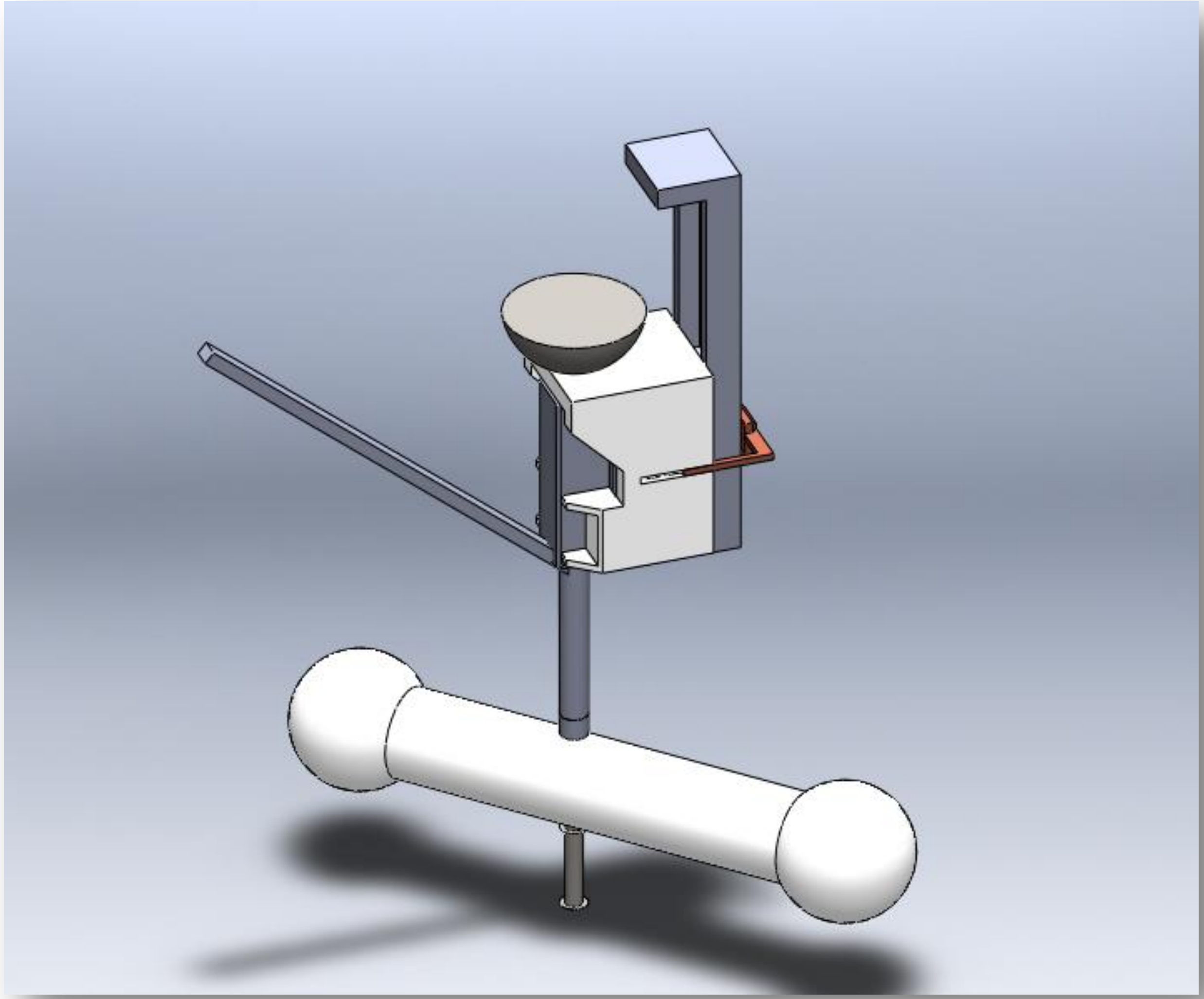


Figure 19. Our hydraulic design (solidworks) v2.0 in its lowered position.

Final Design: Locking Mechanism

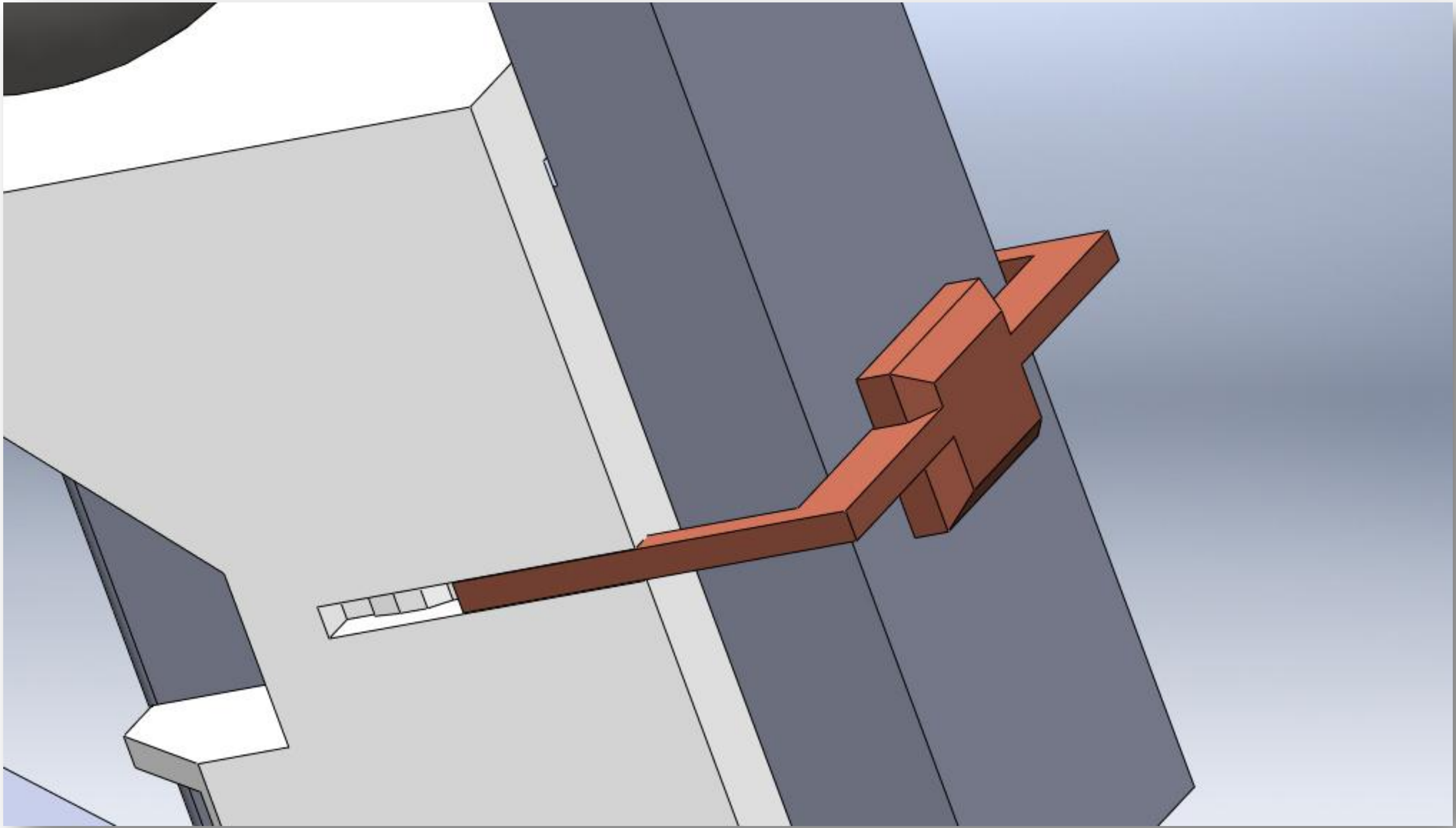


Figure 20: Close-up of the locking mechanism

Final Design: Locking Groove

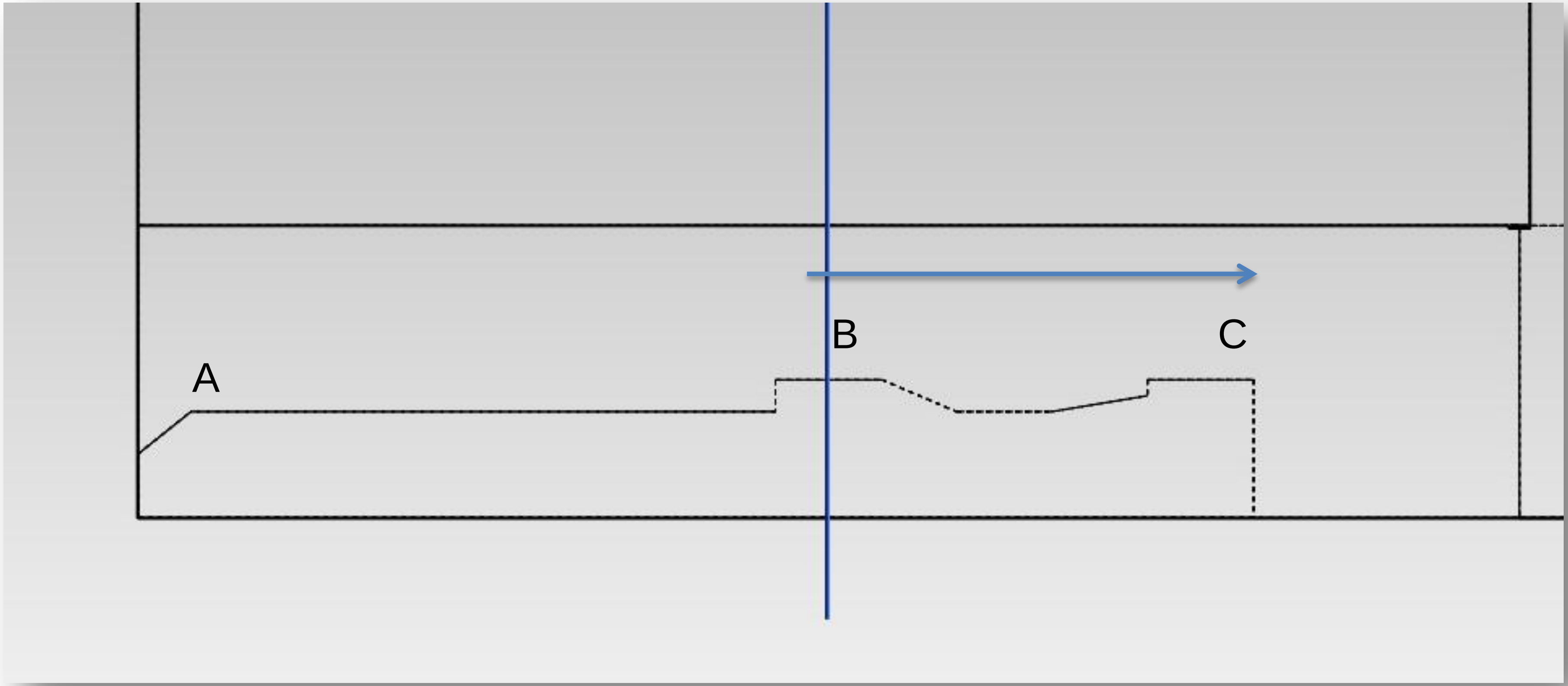


Figure 21: Close-up of the locking Groove

Future Work

- Complete Solidworks design
- Testing
  - Axial force
  - Non-newtonian fluid
- 3-D print prototype
- Test prototype

Figure 22. 3D printer [14]

Acknowledgements

Dr. Austin Crow

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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

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[4] http://wmclarkandson.wordpress.com/2009/06/05/new-clark-hydraulics-catalogue/

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

[6] http://www.mpsmedicalsupply.com/Catalog/Height-Rods-Measurement-Devices_2/SECA-207-Portable-Slider-Infant-Measuring-Rod-Extra-Wide

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[11] http://www.shoprunningfit.com/index.php?main_page=product_info&products_id=747

[12] http://upload.wikimedia.org/wikipedia/commons/1/12/Shear_rate_vs._Shear_stress.png

[13] Allotta 1997 (ABOVE)

[14] http://www.technovelgy.com/ct/Science-Fiction-News.asp?NewsNum=2605