



Department of Biomedical Engineering
University of Wisconsin - Madison

Graduated Bowman Probes

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Client: Dr. James Law

Advisor: Dr. Walter Block

Overview

- Lacrimal Complications
- Clinical significance
- Previous Probe Design
- Where we currently stand
- Potential manufacturing approaches
- Probe and Phantom Testing
- Timeline for UW-Hospital implementation
- Acknowledgements and references

Lacrimal Complications

- Nasolacrimal Duct Obstruction (NLDO) impacts **6-20%** of newborns [1]
- Duct obstruction leads to improper fluid drainage and eye irritation [2]
- Treatment for NLDO utilizes a Bowman's probe that is inserted into the punctum for 60 seconds
- A graduated Bowman's probe allows for increased accuracy in duct insertion procedures
- Typical Bowman's probes are made of stainless steel with chromium or nickel alloys

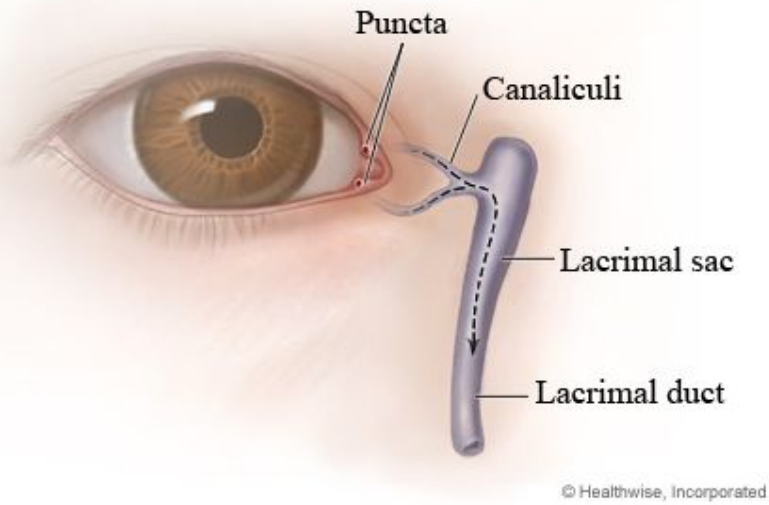


Figure 1 [3]: Diagram of the lacrimal drainage system

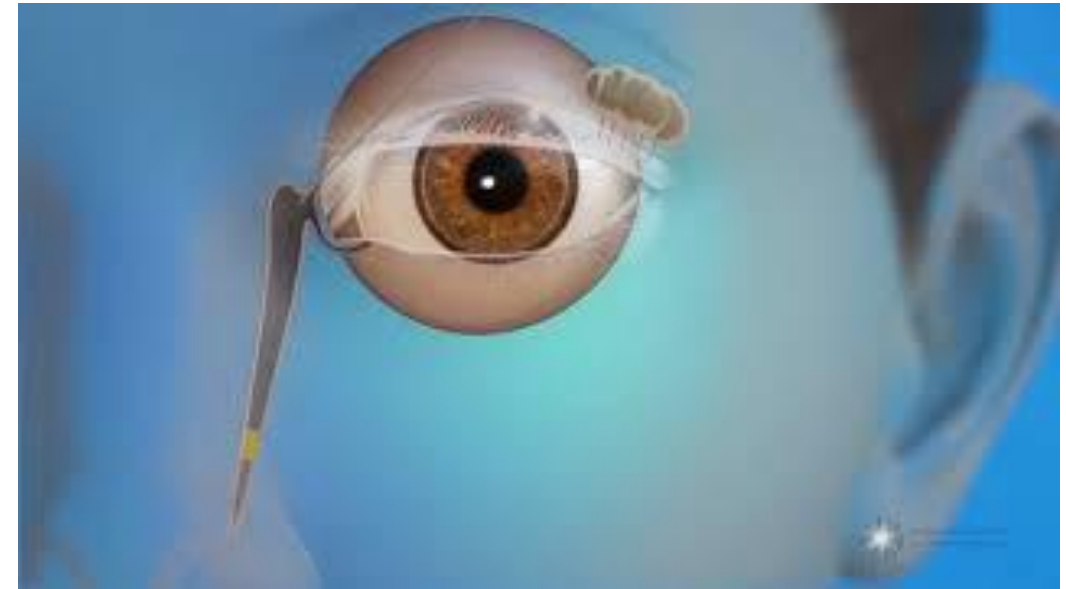


Figure 2 [3]: Video of NLDO procedure

Clinical Significance

Client

- Dr. James Law, MD
- Oculofacial Plastic Surgery Fellow in the UW Madison Department of Ophthalmology and Visual Sciences



Figure 3 [4]: Dr. James Law

Problem Statement

- Currently, there are no available graduated bowman probes available on the market
- Bowman probes are essential for diagnostic accuracy of lacrimal system pathologies, but current probes, without graduation markers, rely on subjective analysis

Previous Probe Design

- Fabricated six prototypes of 6", 0000-000, 00-0, 1-2, 3-4, 5-6, 7-8 sized AISI 420 German stainless steel Bowman Probes.
- LasX 200W laser to create additive markings every 2.5mm ranging 35mm
- Capable of withstanding autoclave environment (135C and 15-20 psi) [5]
- ISO-13485:2016 compliant [6]
- Performed cadaver, tissue-pull, autoclave, accelerated life, and uniformity testing

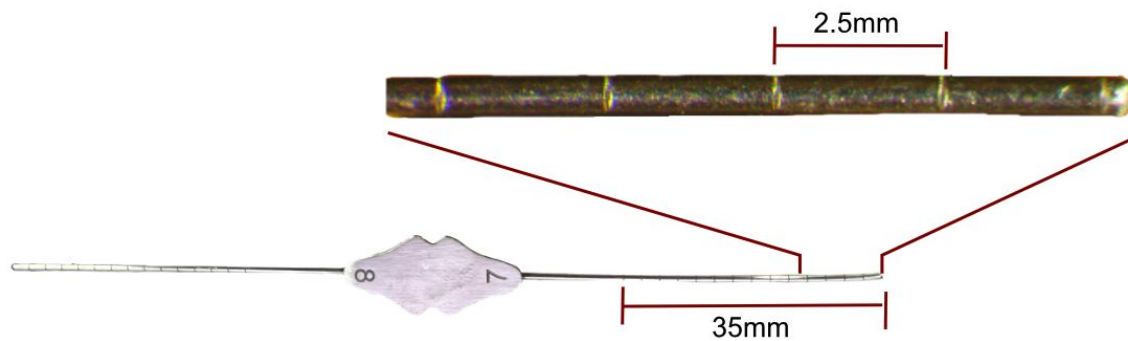
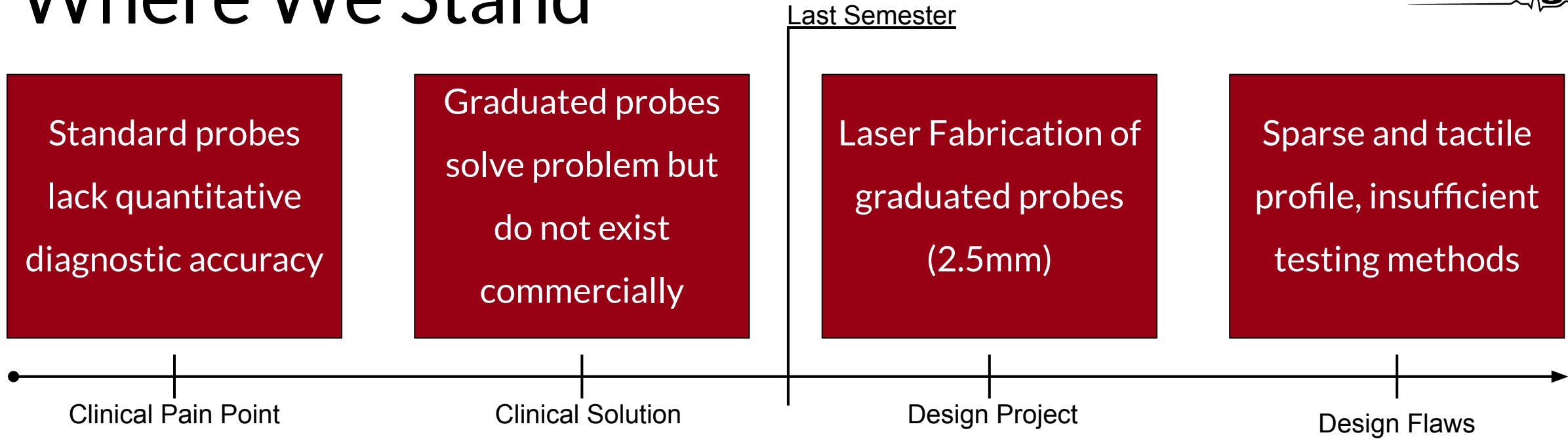


Figure 4: Graduated Bowman's probe prototype



Figure 5: Probe holder for laser marking

Where We Stand



Improvements & Goals

- Probes with finer graduation developed through a refined and repeatable fabrication process
- Development of a lacrimal apparatus phantom for 'tissue-snag' testing applications and for UW medical student procedural practice
- IRB Approval and UW-Hospital Implementation

Graduated Probes

Design

- Graduation markers every 1 mm along the shaft of the probe
- 5 mm distinction for easier visual inspection
- Visually legible graduations yet a smooth smooth, minimally tactile surface profile

Fabrication

- Laser induced engraving
- Utilizing external contract of Schumacher Machinery LLC.
- Repeatable and accurate fabrication

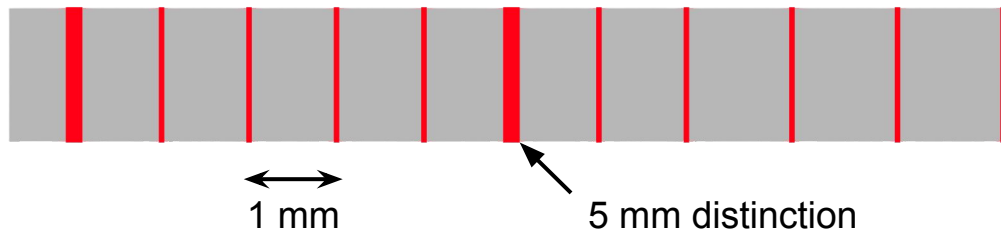


Figure 6: Diagram of updated finer graduation scheme.

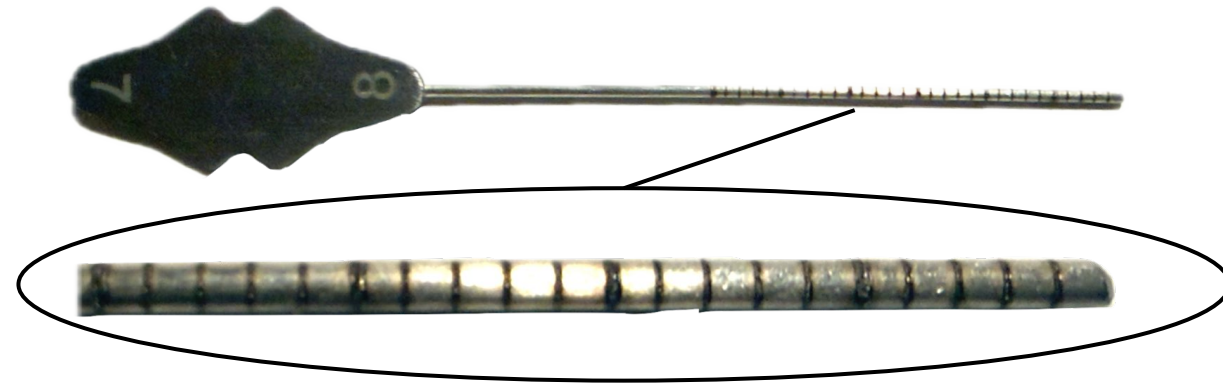


Figure 7: 1mm graduated Bowman probe prototype with 5mm darker distinction from Schumacher Machinery LLC.

Lacrimal Phantom

External Shell

- Flexible material shell to allow for probe entrance and turning as seen during procedure
- Material must be elastic and deformable
 - Allows for repeatable use for medical education and testing

Internal Coating

- Nasolacrimal system lined with stratified epithelium and slippery mucosal secretion [7]
- Biomaterial must be hydrophilic and malleable to mimic tissue surface and mechanical properties

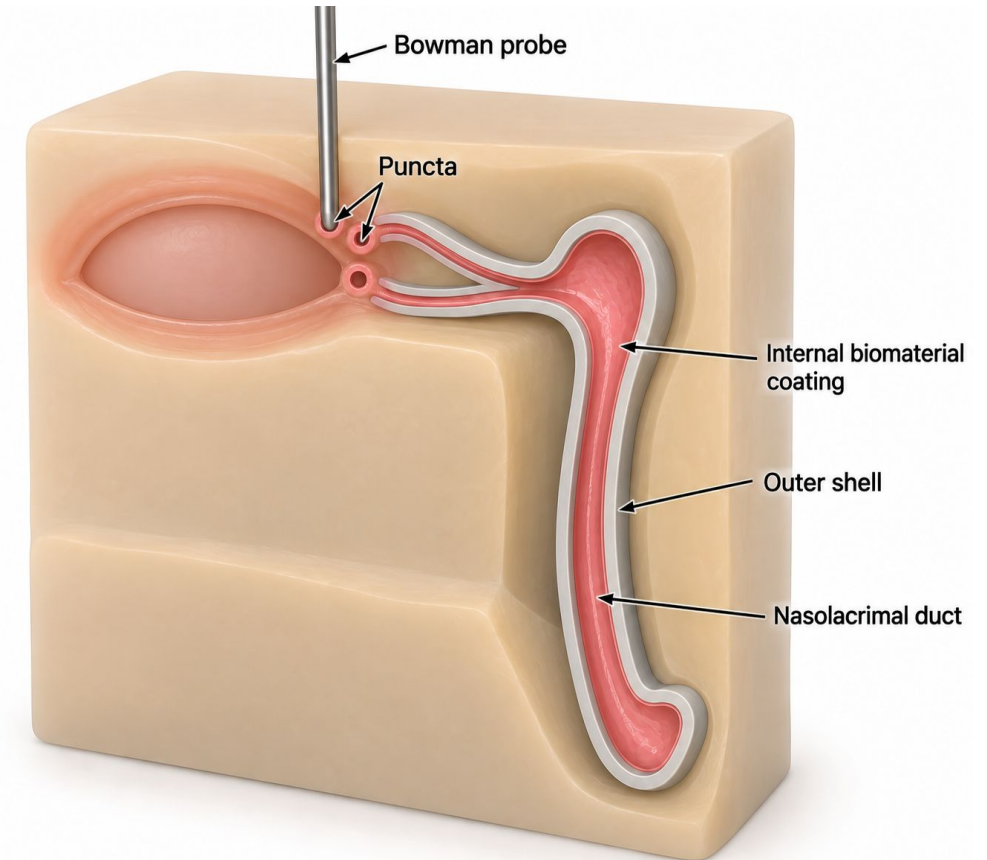


Figure 8: Nasolacrimal phantom depicting external shell and internal coating within anatomical frame

3D Printing

Pros

- High anatomical accuracy
- Feasible and repeatable fabrication
- Direct access and cost-effective

Cons

- Difficulty in fabricating thin-wall structures
- Differences in material hardness and mechanical properties
 - Human Tissue: Shore Hardness 30A [8]
 - SuperFlex Resin: Shore Hardness 80A



Figure 9 [8]: Formlabs Form 4 Liquid Resin 3D Printer



Figure 10 [8]: SuperFlex liquid resin shore hardness 80A

Injection Molding

Pros

- Accurate geometry and curvature to the nasolacrimal canals
- High pressure water creates hollow tube structure [9]
- Easily repeatable process

Cons

- Specific material choice is required to create a uniform hollow center [9]
- Only would create the external shell of the mimic
- Difficult to create a uniform canal inside the shell of the mimic

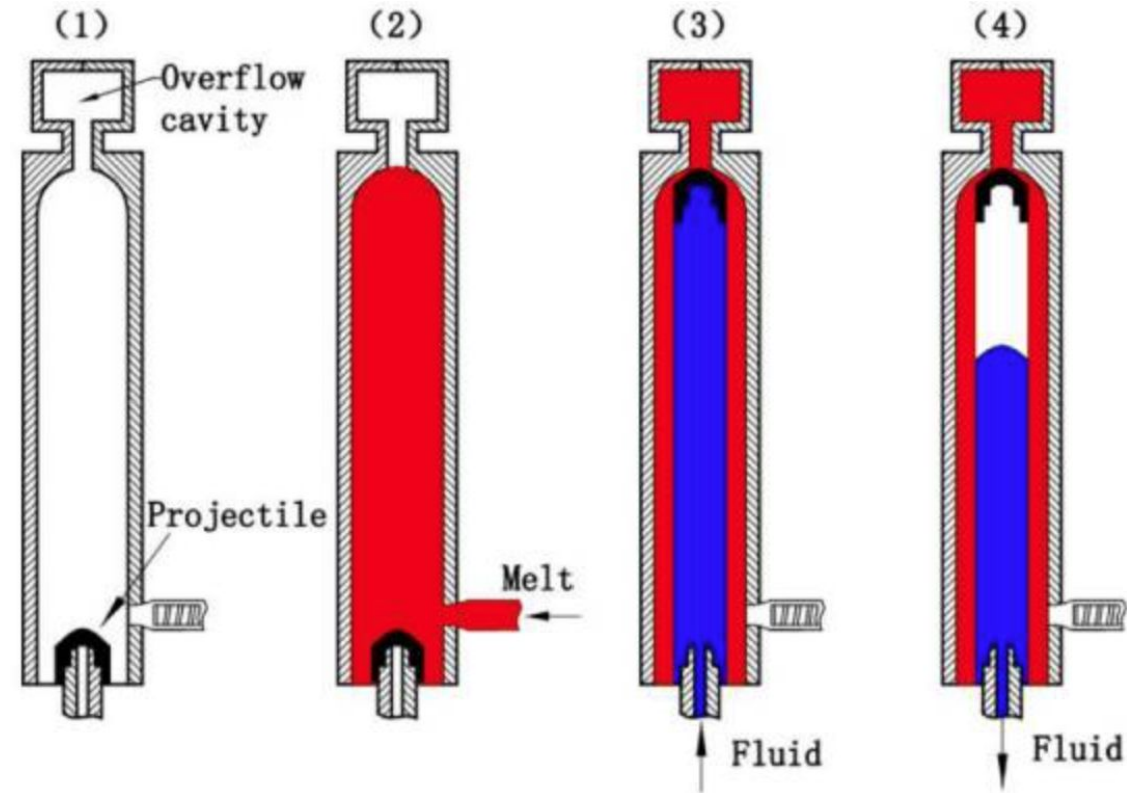


Figure 11 [9]: Forming process of water assisted injection molding

Electrospinning

Pros

- Material mimics elasticity properties and texture of nasolacrimal canals [10]
 - nanofibers similar to native ECM
 - can align fibers to match that of the native tissue
- Cost effective and repeatable fabrication

Cons

- Inadequate strength for load bearing due to high porosity [10]
- Difficult to produce accurate 3D geometry
- Very sensitive to environmental factors [11]
 - temperature
 - humidity

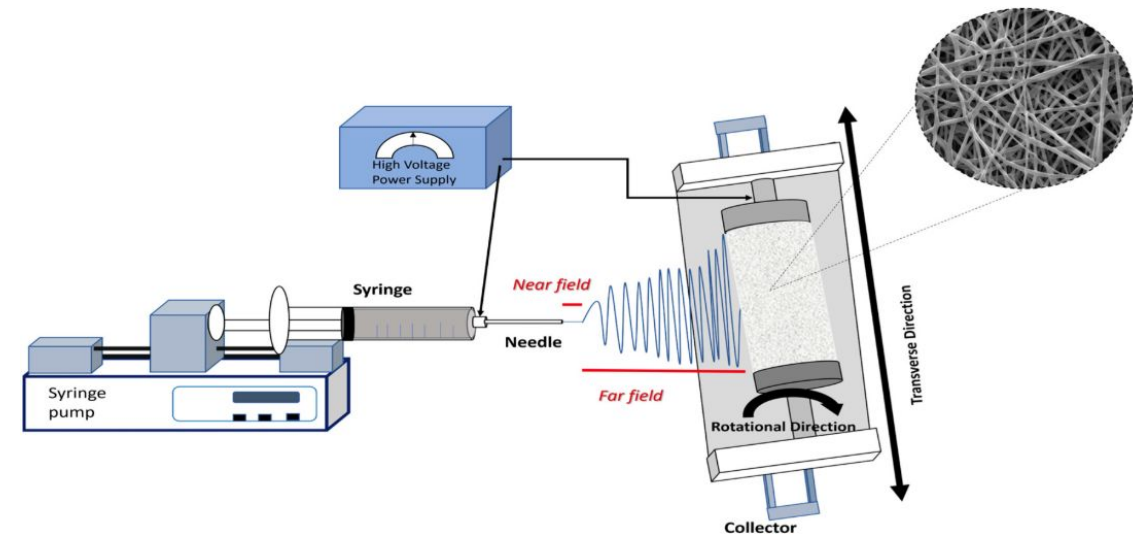


Figure 12 [11]: Schematic representing electrospinning setup

Graduated Probe Testing

Test	Last semester	This semester
Autoclave	3 cycles Weight + Visual inspection	More cycles + contrast metric Quantify fading
Accelerated life	One 48-hour cycle + Visual inspection	Checkpoints + contrast metric Track when fading begins
Graduation uniformity	Known length Calibration + Variable positioning	Micrometer + 3D-printed holder Repeatable 1 mm checks

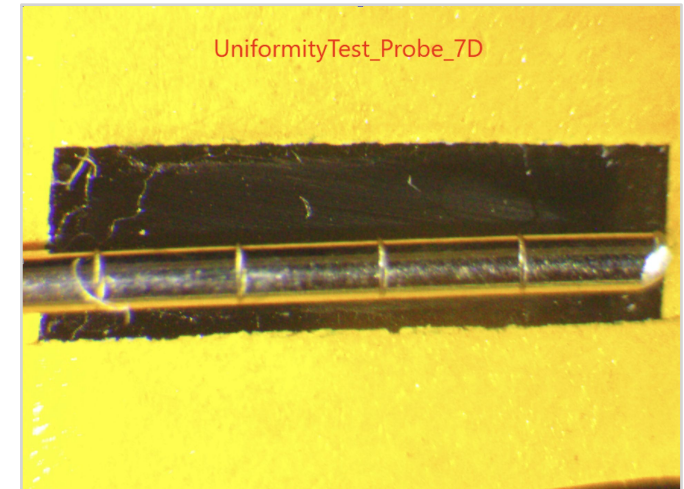


Figure 13: Uniformity testing sample

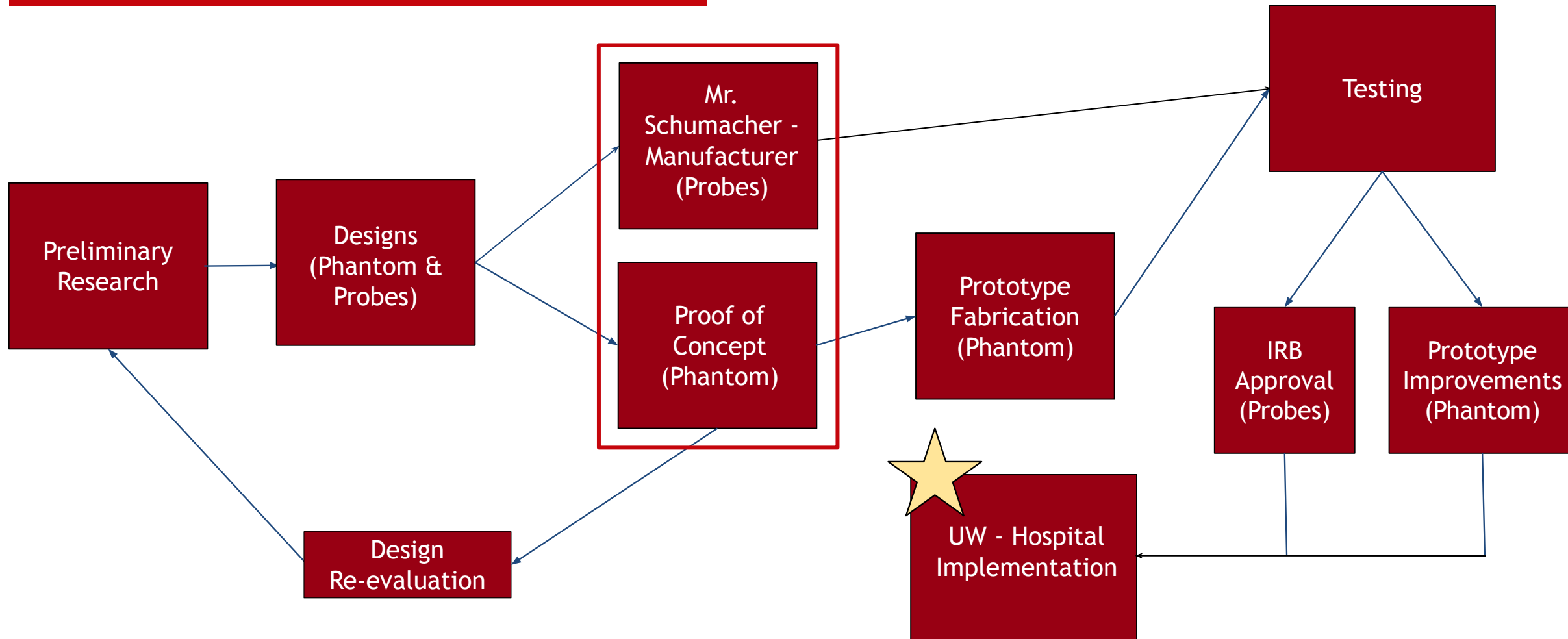
Phantom Testing

Goal: Assess human soft-tissue-like behavior and realistic lacrimal geometry.

Test	Proposed approach	Readout / comparison
Qualitative Similarity	Dr. Law testing + feedback	Overall feel, friction, malleability
Material Behavior	MTS compression and tensile testing	Stiffness + elasticity Compare materials + biological tissue data
Insertion resistance	Force sensor	Force vs. depth Resistance

Future Work

Project Timeline



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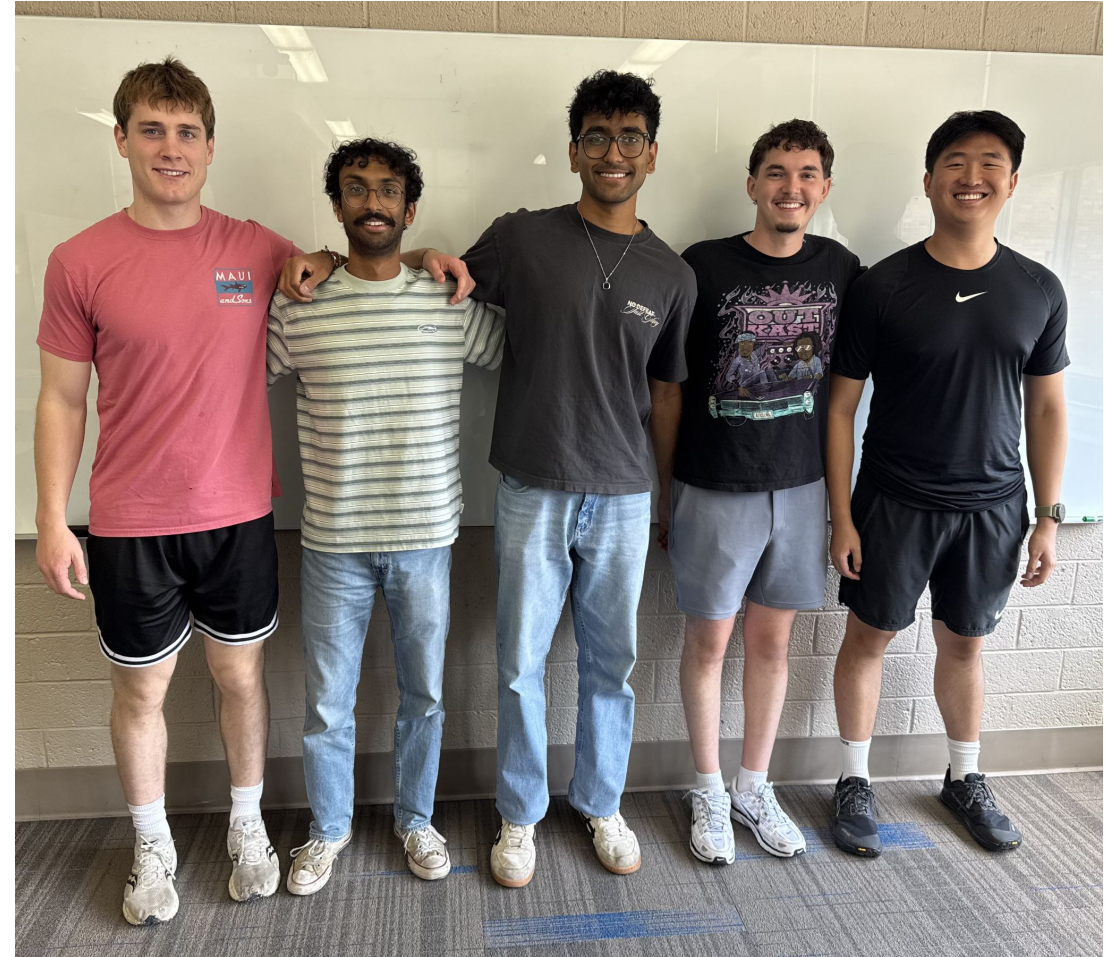


Figure 14: Team Picture, team members from left to right: Caleb White, Neel Srinivasan, Sudhindra Chavadam, Caden Robinson, Kenneth Sun

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Questions?