

Design Matrix

Graduated Bowman's Probes

Team Members:

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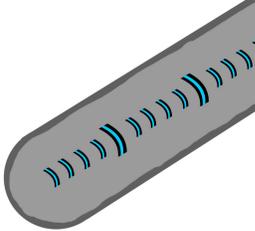
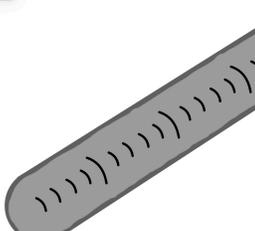
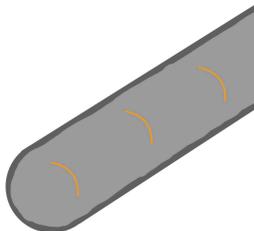
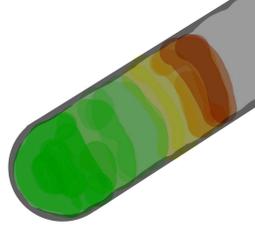
Client: Dr. James Law

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Lab Section: 304

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Table 1. Design matrix for Bowman Probe

		Laser Engraving		Laser Annealing		Electroplating		Thermochromism	
									
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Accuracy	25	5/5	25	5/5	25	5/5	25	3/5	15
Patient Safety	25	3/5	15	4/5	20	4/5	20	2/5	10
Ease of Data Acquisition	20	5/5	20	4/5	15	3/5	12	2/5	10
Durability	15	2/5	6	5/5	15	5/5	15	5/5	15
Ease of Fabrication	10	4/5	8	2/5	4	2/5	4	3/5	6
Affordability	5	5/5	5	2/5	2	2/5	2	2/5	2
Total	100	SUM	79	SUM	81	SUM	78	SUM	58

Design Descriptions:

Design 1 - Laser Engraving: The first design brings engravings to the bowman probe.e

Design 2 - Electroplating: The second design consideration is electroplating. Electroplating is the process of producing a metal coating on a solid substrate through the reduction of cations of the chosen metal via an electrical current. The two chosen substrates in this case would be the stainless steel bowman probe, acting as the anode, and a secondary, separate colored metal, such as a dark titanium, as the cathode. Using electroplating, tiny strips of metal coating would be plated onto the bowman probe in specific locations through controlled masking with tape or wax. These tiny strips would indicate millimeter measurement markings along the shaft of the probe, providing a visible graduation for live, clinical use during ophthalmological procedure.

Design 3 - Thermochromism: The final design features a thermochromatic coating that is intended to change the probe's color depending on the insertion depth into the human body. Thermochromic coatings have microcapsules that contain encapsulation agents and pigments such as urea-formaldehyde and leuco dyes respectively. When heated, the solvent inside the capsules melts which allows the weak acids to interact with the leuco dyes. This process changes the capsule's chemical composition and results in the probe's surface changing color. Upon use, this design would require doctors to maintain nasolacrimal duct probe insertion until the thermochromic coating activates and changes the probe's appearance. After the probes change in color, the doctor would need to measure the range of color manually with a measuring tool.

Determination of Criteria and Justification of Scores:

Accuracy - This criteria refers to the probes ability to accurately measure the depth of the probe that has been inserted into the nasolacrimal duct. Markings must be made at the correct depths, and must have the marking be easily discernible so the user reports the correct value. Accuracy is of critical importance (25%) to ensure the user is able to make accurate measurements of the depths of blockages to inform treatment. Laser Engraving and Electroplating both scored 5/5 in accuracy, due to their precision of machining, and clearly marked depths. Thermo-chromism received the lowest score of 3/5 due to the less direct nature of the measurement. There are a number of factors that might influence the accuracy of the Thermo-chromism measurement, including diverse internal temperatures, length of exposure, and difference in how color is measured between clinicians, ultimately decreasing the accuracy of the design.

Patient Safety - Patient safety refers to the probes ability to not harm or negatively affect the patient during standard use. To ensure safety, designs must have a smooth exterior that can not get caught on anything when inserted into the nasolacrimal duct. Additionally, the probe and alterations to the probe must be biocompatible, ensuring that it has no negative effects due to chemicals or materials used. Patient Safety is tied for the highest weighting, 25%, as the probe must be safe to be a beneficial improvement to standard bowman probes. Electroplating scored the highest score of 4/5 due to having smooth markings that can't catch on anything in patients. The second highest score of 3/5 was awarded to Laser Engraving, slightly lower than Electroplating, due to having engravings that could possibly catch during use. Thermo-chromism scored 2/5, the lowest score in this category. This is due to the use of weak acids and encapsulation agents such as urea-formaldehyde, which could have potential biocompatibility issues, especially if the surface of the probe is broken in some way.

Ease of Data Acquisition - This criterion refers to the simplicity of probe measurement. Specifically, this category assesses how easy the nasolacrimal duct insertion depth can be determined from the design. This category is quite important as the user's ability to easily ascertain depth insertion is of importance, hence its weighting of 20%. The laser engraved design earned the highest score of 5/5 due to its clear line markings at 1 mm & 5 mm offering simple direct measuring capabilities. The electroplating design placed second in the rankings at 3/5 due to its infrequent line markings. While this design features accurate line markers at 5 mm intervals, the exact measurement would prove difficult to gauge and would rely on the user's estimation. The final design featuring thermochromatic coatings scored a 1/5 in this category, the lowest of the 3 chosen designs. The rationale behind this decision is because of the lack of markings on the probe. While this design features a non-surface-penetrating method of graduation, the inverse effect is that doctors must measure the range of color change using their own measurement tools, ultimately making data acquisition more difficult.

Durability - This criterion is relatively straight forward and highlights the physical properties of the different designs of these probes. While the probes must be strong enough to prevent any form of breakage during the procedure, they must also be flexible enough to navigate the different canals in the nasolacrimal pathways. Durability also relates to the changes made from the different forms of 'graduating' these probes. The laser engraving design scored the lowest because the probe's properties and structure are being manipulated. While re-coating it with a new material to smoothen out the edges seems like a good option, a new material introduced into the probe could cause its structure to behave differently to what an ophthalmologist is used to; it could be too stiff or too flexible, which is why it scored the lowest. The other two prototypes'

physical structure is not being manipulated at all, meaning that no change will be made to their properties, resulting in them earning the highest score for this criteria.

Ease of Fabrication - The ease of fabrication criterion refers to both the general feasibility and technical finesse required for the consistent execution of the described fabrication method. This criteria provides insight into what design ideas are realistic answers to the problem at hand, and what design ideas are built on a hypothetical solution. The design that scored highest in this criterion was the laser engraving design, earning a 40%. The group has experience with laser engraving and therefore understand the fundamental process associated with the specific fabrication method. Laser engraving would eliminate the human error associated with fine measurement graduation and therefore provide consistent, precise results that could be feasibly accomplished in the given time frame. The other two designs, electroplating and thermochromism, scored lower, with respective scores of 20% and 10%. Both of these design ideas introduce technical practices the group is unfamiliar with which grows the opportunity for error during the fabrication process. Similarly, these fabrication practices require a strong chemical intuition that again may very easily introduce inaccuracy.

Affordability - The affordability criterion refers to the cost associated with the execution of each design idea. The design should desirably be cost effective in both a singular instance, and over repeated fabrications. The design that scored the highest was design 1, laser engraving. All the design requires is use of the laser at the Wendt Commons Makerspace, as well as potentially a biocompatible resin to fill in the engraving incisions to prevent tissue compromise. The other designs each received a 20% score, as both would require the continuous purchase of multiple coating and fabrication materials. They also require equipment less readily accessible as the laser, which could boost fabrication costs.

