Using Engineering Techniques to Convert a Goldmann Applanation Tonometer to a Handheld Device

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Introduction

Glaucoma is the leading cause of irreversible blindness globally, with an estimated 76 million suffering from the condition in 2020 [1]. Treating and preventing glaucoma costs an estimated $5.8B annually in the US [2]. The condition disproportionately affects lower socioeconomic levels due to poor access to eyecare and medications [3] [4]. Early detection of glaucoma is crucial to prevent the progression of the disease and eventual blindness.

The Goldmann Applanation Tonometer (GAT) is the gold standard tool for measuring intraocular pressure (IOP) but is fixed and cannot be used on patients who are bed-bound or outside the clinic. One way of increasing the accessibility of glaucoma detection and monitoring is with handheld tonometry options. However, handheld tonometers such as the Tono-Pen can be a costly additional expense, making them unfeasible for lower-funded clinics.

Figure 1. (A) Tono-Pen [5], (B) Perkins Tonometer [6]

Purpose

Engineering students, led by resident physicians, developed a device that converts a GAT into a handheld tonometer.

The ultimate goal is to create a portable device that maintains the accuracy and functionality of the GAT while being easy to use and manufacture.

Methods

- Device based on **Haag-Streit AT-900** GAT
- Modeled on **SolidWorks**
- **3D-printed with PLA** using Prusa SL1S SPEED 3D printer and Curing and Washing Machine CW1S BUNDLE
- **Iterative design process**
  - Design and 3D print prototype <--> basic bench tests

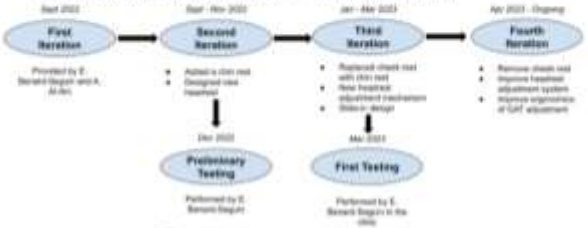

Figure 2. Iterative design process map.

Prototype

The device is designed to allow a Haag-Streit AT-900 GAT to slide in; the device is securely held in the casing.

- **Headrest** controlled by a gear and can be incrementally adjusted
  - Physician remains stable while taking measurements
- **Adjustable lens holder** secures a jeweler's lens
  - Physician can change distance of lens to the correct focal distance
- **Knob on handle** connects to GAT dial with pulley system
  - Physician can easily adjust GAT knob while measuring IOP
- **Handle** allows physician to maneuver device
  - Holds 9V battery powering **blue LEDs** that are wired into device to activate fluorescein
- **Right side** of design has **cut-out section**
  - GAT can slide back onto a slit lamp while still in the casing

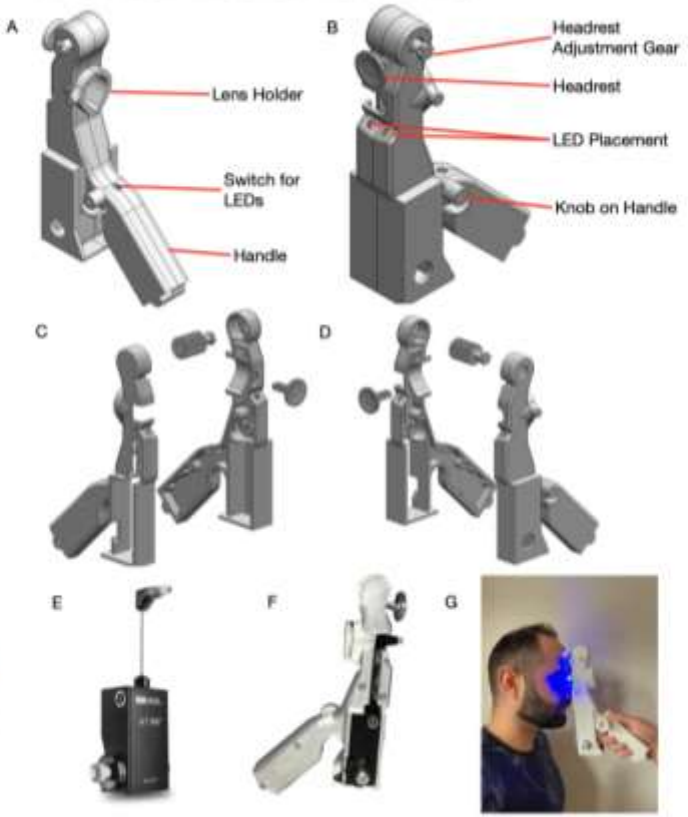

Figure 3. (A) Back-left view of device. (B) Front-left view of device. (C) Front-right exploded view of device. (D) Front-left exploded view of device. (E) Haag-Streit AT-900 Goldmann Applanation Tonometer [7]. (F) 3D printed prototype. (G) Demonstration of earlier functional device prototype being trialed by authors.

Materials & Costs

Blue LEDs and Battery Adapter	~$10
PLA Filament	~$8
Jeweler's Lens x1	$6.63
Screws	$0.10
9V Battery x1	$9
Total	$33.73

Table 1. List of materials used and estimated associated costs for one 3D printed device.

- Jeweler's lens marked as having magnification of 20x
- PLA filament was 1.75mm, with printing temperature of 210° C and bed temperature of 60° C

Preliminary Testing Results

- Verified **activation of fluorescein** by blue LEDs
- **Assembly** of device was **fast and simple**
- **Single-hand operation** of GAT during IOP test successful
- IOP successfully measured - similar readings to mounted GAT.
- **Lens focal distance hard to find** to get accurate measurement
- **Adjustment knob hard to adjust** while taking measurement
- **Headrest** did not provide ideal ergonomics

The lens system, adjustment knob, and headrest must undergo further development and bench testing to increase the accuracy and ergonomics before clinical tests can begin.

Conclusions & Future Work

Collaboration between ophthalmology and engineering has yielded a promising prototype that addresses the need for affordable methods of portable tonometry. Future iterations must involve **bench testing to refine the device's usability and function** before clinical tests can begin. We will also aim to standardize the modified GAT for reintegration onto a slit lamp.

Ophthalmology and Engineering

Figure 4: Bridging the gap between Biomedical Engineering and Ophthalmology.

Acknowledgements and References

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