Winter 2020

Integrated Dentistry Face Shield

Noah Glass
neg21@zips.uakron.edu

INTEGRATED DENTAL FACE SHIELD

By

Noah Glass

Final Report for 4600:497 Honor Design Fall 2020
Faculty Advisor: Dr. Kannan
Faculty/Honors Advisor: Dr. Sawyer
Faculty/Honors Reader 1: Dr. Gopal
Faculty/Honors Reader 2: Dr. Pavlick

11 December2020
Project No. 09

Abstract:

Currently, the United States and the entire world is experiencing a global pandemic that has drastically changed the way we go about our everyday lives. Dr. Pavlik, a local dentist is one such person who has had to alter his normal dentistry routine to one of extreme caution while working with patients. His day to day job puts him at a high risk of being exposed to Covid-19 by actively working in a proximity with patients. Dr. Pavlik's current dentistry equipment is lackluster in its compatibility with his safety equipment. To help minimize exposure to Covid-19 for Dr. Pavlik and his associates, my project will attempt to integrate his necessary dentistry equipment into a face shield that is both functional and safe.

TABLE OF CONTENTS

1. Introduction

Currently, the United States and the entire world is experiencing a global pandemic that has drastically changed the way we go about our everyday lives. Dr. Pavlik, a local dentist is one such person who has had to alter his normal dentistry routine to one of extreme caution while working with patients. His day to day job puts him at a high risk of being exposed to Covid-19 by actively working in proximity with patients. Dr. Pavlik's current dentistry equipment is lackluster in its compatibility with his safety equipment. To help minimize exposure to Covid-19 for Dr. Pavlik and his associates, my project will attempt to integrate his necessary dentistry equipment into a face shield that is both functional and safe.

Today in the dental product industry there are multiple face shields that are compatible with dental loupes that are used for magnification and lighting. These face shields are simply designed to accommodate for the extra facial space needed to utilize dental loupes and wear a face shield.

The product of this project will differ from existing designs as it will not accommodate dental loupes but eliminate their need. The face shield will be equipped with a similar LED lighting device and magnification device therefore replacing the need for dental loupes. This product will hopefully offer a cheaper, functionally simpler, and similar product to dental professionals.

1.1 Objectives

The objective of this project is to produce a product that meets all of Dr. Pavlick's requirements for the face shield. His product requirements are as follows: an LED head light comparable to the ones utilized in dental loupes, an adjustable 2-3X magnification with clear and undistorted image quality, comfortable and lightweight for prolonged usage, affordable to manufacture, and most importantly it must meet medical grade safety standards. Given the time frame for the project is roughly three months all requirements for the design should be met.

Undoubtedly, the most complicated aspect of the design will be the adjustable magnification. To account for the necessary customization needed for the product, a 3D printed headpiece will likely be used. Also, the design must be proven to be safe and will be tested to ensure it meets safety standards.

1.2 Design Strategy

For the design of this product, the methods used in the class Concepts of Design will be applied. The design process will be split into a conceptual design and embodiment design process. The conceptual design will focus on brainstorming product ideas and evaluating the effectiveness of these ideas by using an objective tree, solutions list, morphological chart, and concept sketches. The embodiment and detail design will be concerned with the best design from the conceptual design stage. In this design stage, Solidworks will be used to generate parts brainstormed from the conceptual design stage and the connections for these parts will be developed. Also, parts will be picked that meet the product specifications. A final assembly model will also be created.

After the design stage, the product will enter the manufacturing stage where it will be 3D printed using The University of Akron's 3D printing facilities. The additional parts including an LED light, fabric for comfort, and magnification will then be attached to the 3D printed headpiece.

1.3 Verification

For testing of magnification, lighting, and comfort Dr. Pavlick will evaluate each aspect by utilizing the product at his work. Given that he is the desired end user and an experienced dentist his input on the effectiveness of the design is the best measurement. On the topic of safety, the face shield can be tested to see if it ensures protection from a viral load which could be simulated.

Tolerance for the 3D printed headpiece should not be an issue as the 3D printers at the university are well maintained and the design will not require any small tolerances. The MakerBot can consistently hit tolerances of +- 0.05" which will be more than enough for this product.

1.4 Potential Market

A few potential markets for this integrated face shield exist. The most straightforward market is Dentists who currently use Dental Loupes, but have trouble using them with a separate face shield. This product could offer a better, cheaper alternative given that the average price of Dental Loupes is 850$ to 1250$ for a high-quality pair. Other health professions who use magnification in their practice such as surgeons could also have an appeal to this product.

1.5 Schedule

The project needs to be completed by the end of November leaving approximately three months for completion as shown in **Table 1**.

Stage of Project	Timeline
Conceptual Design	8/24 - 9/11
Embodiment Design	9/14 – 10/02
Manufacturing	10/05-10/23
Testing	10/26-11/13

Table 1 Timeline for completion of the Honors Project

The three weeks for each stage of the project were similar and determined from previous work in the Concepts of Design class and previous engineering work while on Co-Op.

2. Conceptual Design

The conceptual design will focus on brainstorming ideas for the desired product. This section includes a weighted objective tree, a solution list, a morphological chart, different concept sketches, and a weighted decision matrix. Using the tools mentioned a final concept will be determined.

2.1 Weighted Objective Tree

For a clear picture of what is desired in the face shield, a weighted objective tree will be used. The weighting factors highlight what parts of the design are most important and the others that are less critical. The weighting factors will also be used in the weighted decision matrix to determine, which concept sketch will proceed to the embodiment design stage. Dr. Pavlick specified that the most important aspects of the face shield will be safety, the magnification, the lighting, how comfortable it is, and its durability/reusability. These main topics were then broken down into relevant subtopics. This process is shown in **Figure 1** below.

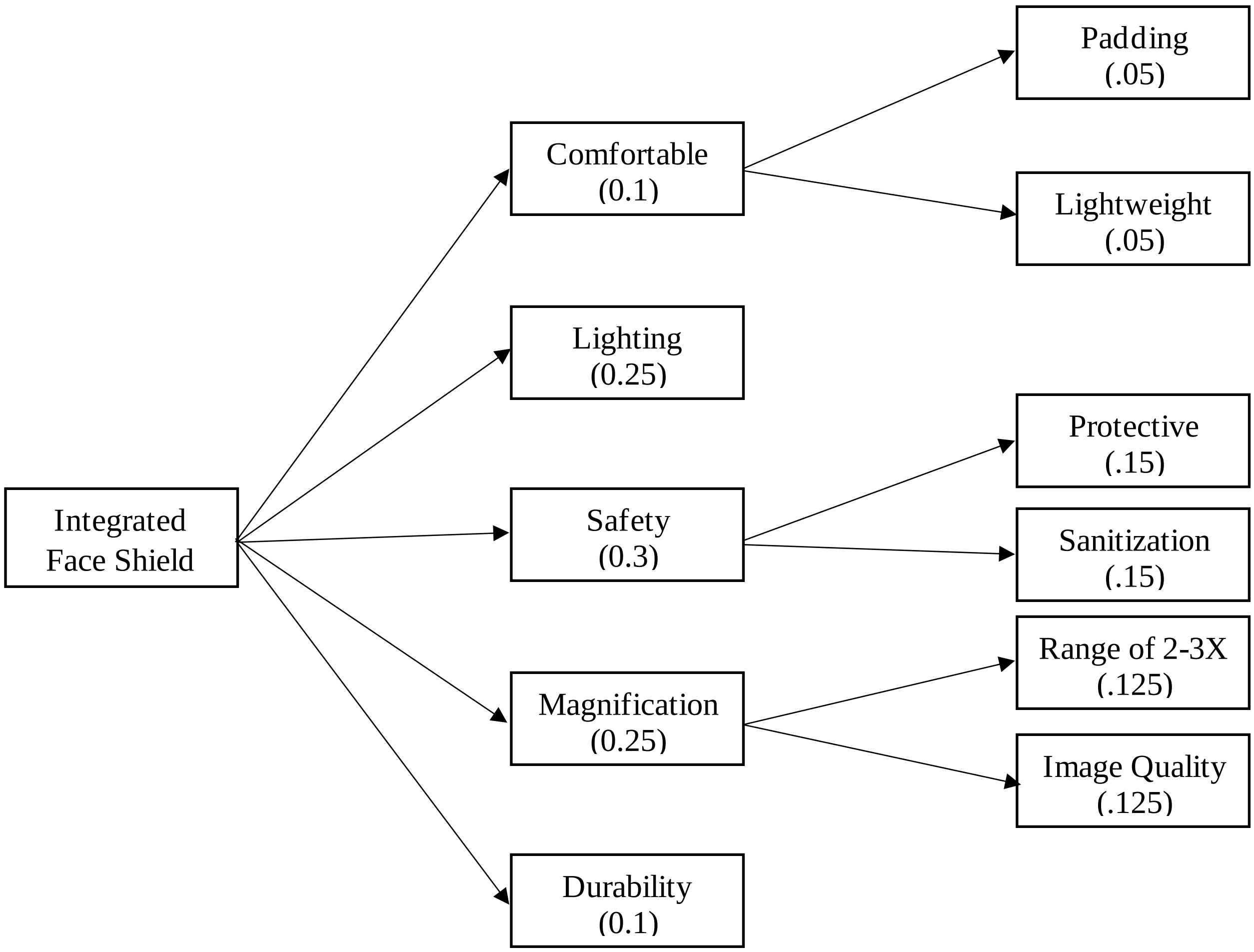


Figure 1 Weighted Objective Tree

2.2 Solution List

To get a better understanding of the possible methods of successfully achieving all the tasks in the weighted objective tree, a solution list was used. The solution list provides a straightforward way of comparing the advantages and disadvantages of possible design solutions.

The first problem considered in the solution list is the type of magnification. There are four types of magnification: relative size, relative distance, angular, and electronic magnification. **Table 2** below shows the method of how each type is achieved and the pros and cons of four magnification types.

Types of Magnification	Method	Advantages	Disadvantages
Relative-Size Magnification	Lessen distance from your eye to visual target	Good for low levels of magnification. Cheap	Only useful for low level magnification.
Electronic Magnification	Camera displays magnified image on monitor	High quality image	Expensive, large setup space required
Relative-Distance Magnification	Actual size of object increased thus increasing retinal image	Good for low levels of magnification. Simplest method. Used in loupes.	Only useful for low level magnification
Angular Magnification	Multiple lenses for stronger magnification	Great for high magnification needs	More expensive and more magnification than needed for project

Table 2 Solution List for Magnification

Besides magnification, the design also needs to incorporate lighting to allow Dr. Pavlick to see into patients' mouths. For this, the selections are limited to a different LED light purchased online or utilizing the clip-on dental light already in use by Dr. Pavlick. Likely, Dr. Pavlick's current clip-on light will be used as it will allow for a cheaper budget and clearly the lighting is sufficient for his current work.

The most important objective of the design is safety. For this, the main consideration is the facial shield geometry. If the face shield is located too far away from the face it may not adequately protect the user from Covid-19 or other germs. Also, if the face shield is not covering the sides, has an opening near the top, and/or does not cover the bottom of the face adequately viral material could infect the user.

It should be noted that the face shield should meet FDA standards for use by health care professionals. The most important standard is that the face shield must "cover the front and sides of the face and provide barrier protection"(FDA). One other important standard is that the face shield must "not be integrated with any other article of PPE such as a face mask, but rather is for use as a standalone face shield" (FDA). For this product, the standards listed above will be met to at least meet some FDA standards. Referencing other face shields that have the proper geometry to meet FDA approval will be useful for this aspect of the design.

Since part of the face shield will be 3D printed it is important to compare a few types of 3D printing filaments. This comparison is shown in **Table 2b** below (3D Insider). For this design, it is desirable that the face shield does not warp, has moderate strength, and is semi-flexible to account for different head sizes. However, the material choice could also be limited by the material available wherever printing occurs.

Filament Type	Material Properties	Cost	Common Applications
ABS	Tough, impact resistant properties, Semi-flexible, Lightweight	20$ for 1.75mm, 1kg spool	Automotive parts, moving parts, toys
PLA	Smooth material finish, moderate strength, and flexibility	20$ for 1.75mm, 1kg spool	Surgical implants, medical suturing
PET	Strong, flexible, no warping, food safe	25$ for 1.75mm, 1kg spool	Cups, plates, food containers
PVA	Biodegradable, water soluble, durable	36$ for 1.75 mm, 0.5 kg spool	Used in textile, and paper industry

Table 2b Solution List for 3D printing filament.

2.3 Morphological Chart

The morphological chart shows different solutions to the design. The different aspects it includes are shown in **Table 3** and include magnification, magnification style, lighting, comfortability, shield band style, shield material, and shield geometry. One aspect that was left out of the morphological chart is how the magnification device will attach to the chosen design. This problem will be addressed in the embodiment design, as it would be very different for each conceptual design solution. Additionally, each of the designs will incorporate foam padding since it is a very simple way to make the product more comfortable.

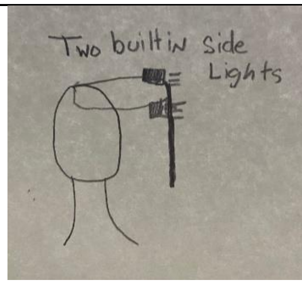
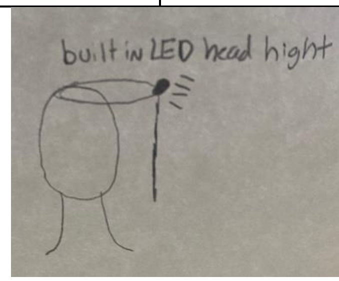
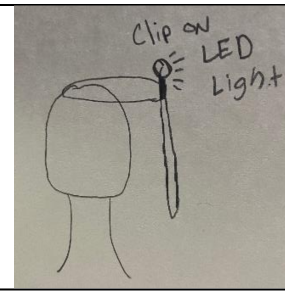
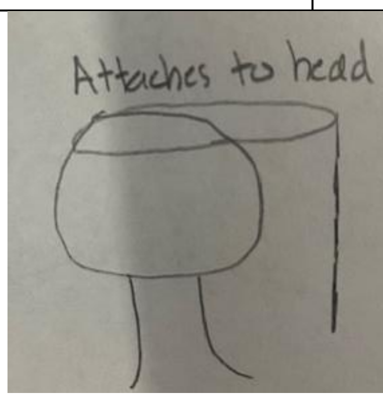
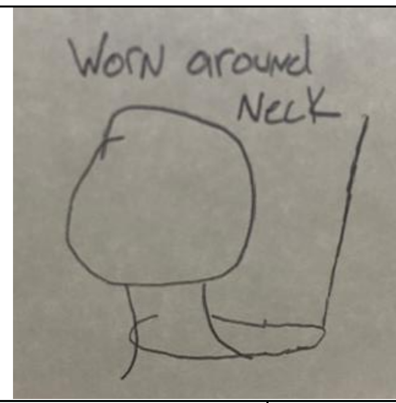
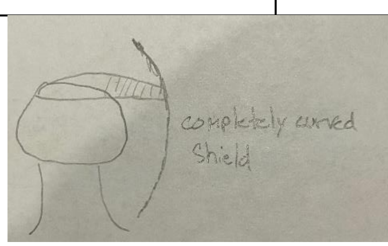
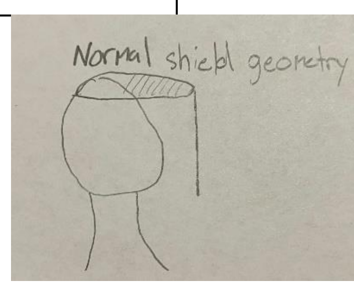
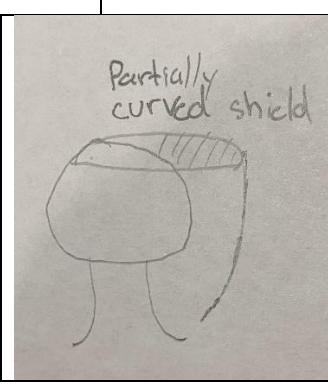
Magnification	Relative Size	Electronic	Relative Distance	Angular
Magnification Style	Adjustable with 2-3X range		Fixed magnification	
Lighting				
Comfortability	Foam padding around shield head piece	No foam padding around shield head piece		
Shield band style				
Shield Material	ABS	PLA	PET	PVA
Shield geometry				

Table 3 Morphological Chart

2.4 Concept Sketches

From the morphological chart five different concept sketches were generated. Each of the concept sketches utilized a different idea from the morphological chart and are shown below in **Figures 2-6**.

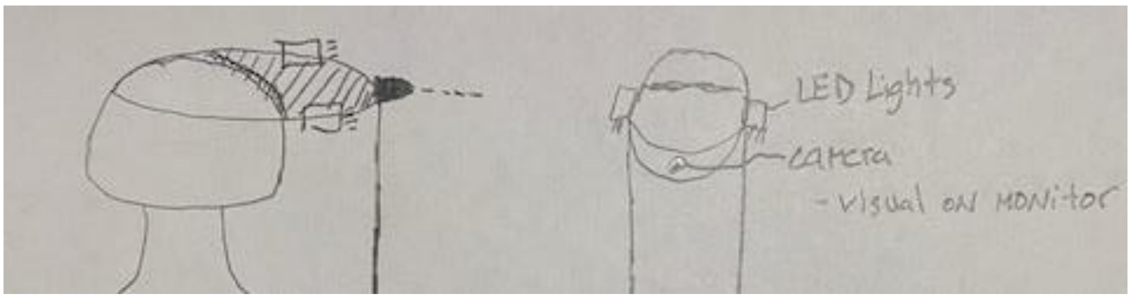


Figure 2 Concept Sketch 1. LED side lights and electronic magnification using a camera.

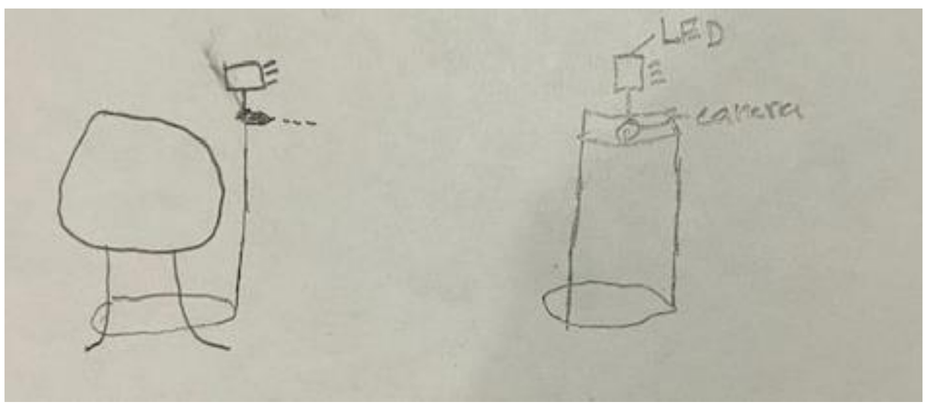


Figure 3 Concept Sketch 2. Clip on LED light and electronic magnification using a camera.

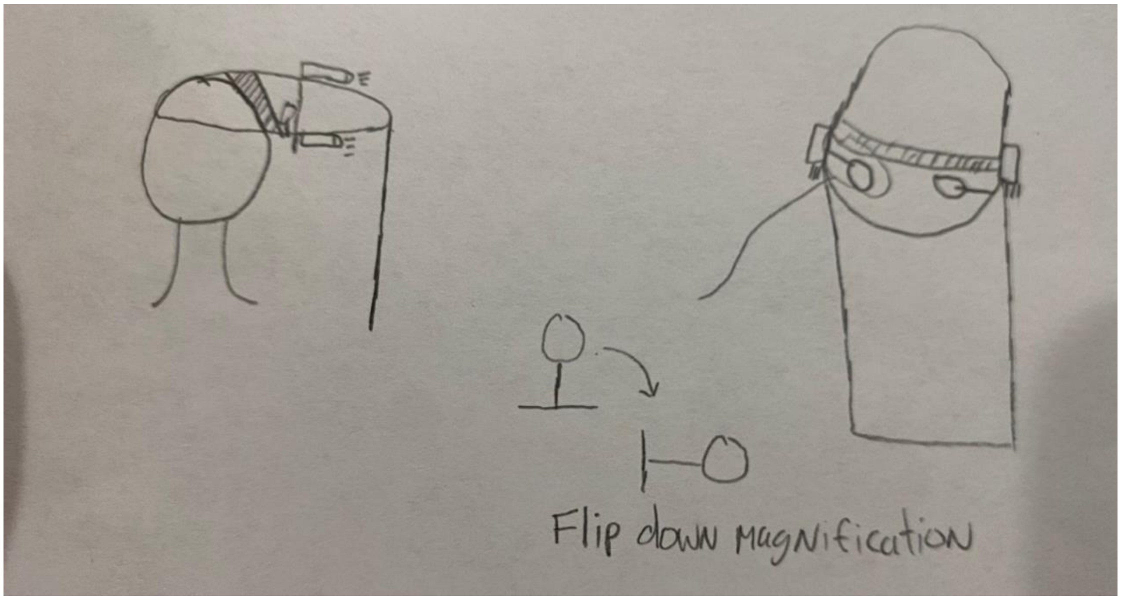


Figure 4 Concept Sketch 3. LED side lights and flip down magnification that could be changed in and out depending on desired magnification.

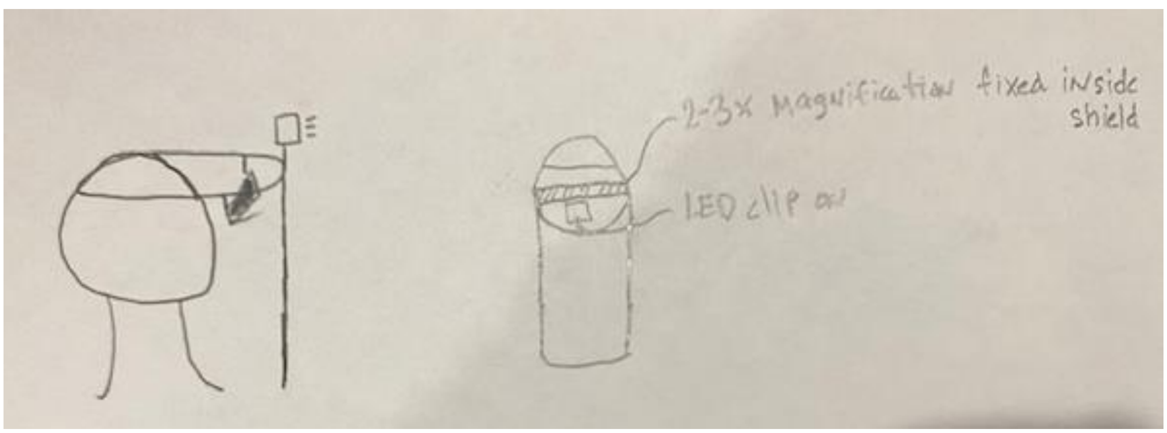


Figure 5 Concept Sketch 4. Clip on LED light and a fixed magnification glass inside the face shield.

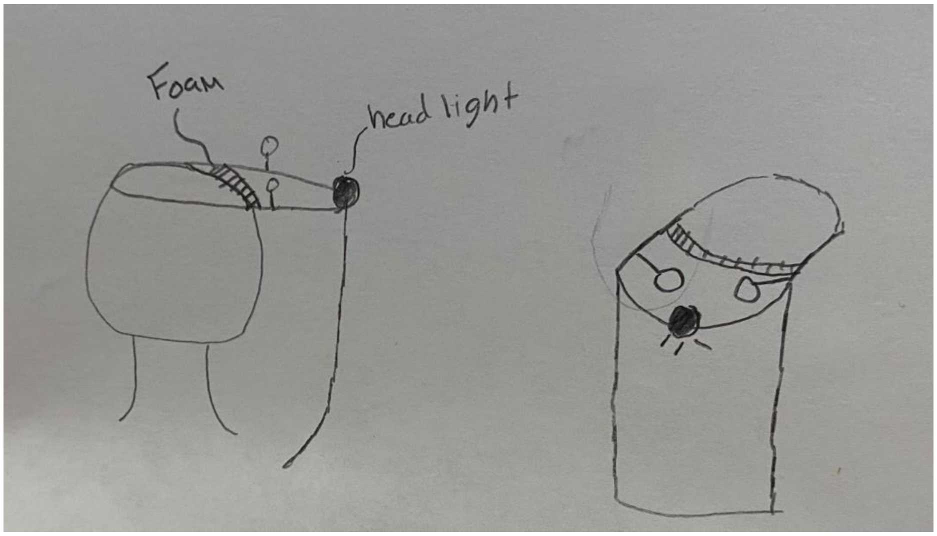


Figure 6 Concept Sketch 5. Front LED light and adjustable flip down magnification.

2.5 Weighted Decision Matrix

The weighted decision matrix shown below was used to select the best conceptual design. The matrix utilizes the weighing factors set in the weighted objective tree and a score for each face shield configuration in each category. The weighing factor is multiplied by each concept score for the respective category. The scores for each category are totaled up and the configuration with the highest total score is representative of the best design.

Evaluation Criteria	Weighting Factor	Shield Configuration 1		Shield Configuration 2		Shield Configuration 3		Shield Configuration 4		Shield Configuration 5	
Comfortable	0.1	4	.4	2	.2	4	.4	4	.4	4	.4
Lighting	0.25	4	1	5	1.25	4	1	5	1.25	3	0.75
Safety	0.3	4	1.2	3	0.9	4	1.2	4	1.2	4	1.2
Magnification	0.25	4	1	4	1	4	1	5	1.25	4	1
Durability	0.1	3	.3	3	.3	4	.4	5	0.5	3	0.3
Totals	N/A	3.9		3.65		4		4.6		3.65	

Table 4 Weighted Decision Matrix

From the weighted decision matrix, shield configuration 4 is the best design. This design utilizes a clip-on light, which is already possessed by Dr. Pavlick and suitable for his work. Also, it has foam padding for comfort. Additionally, the limited moving parts make this design less likely to break or wear down. Finally, even though the magnification is fixed, the user will still get a magnification of 2.5X and can look under the magnification glass just like is done with loupes when needed. This design will enter the embodiment design stage.

3. Embodiment and Detail Design

When designing the base part of the face shield two main embodiment design principles were used. First, was the idea of simplicity. The part was designed to be as simple as possible as will be shown with the magnification and lighting components of the design. Second, the idea of self-help was used. The connection for the magnification piece also serves to support the outmost curvature of the base from bending/warping. The detailed models where these principles can be observed are shown next.

3.1 Part Model

The first part created in Solidworks was the base of the face shield. The appropriate overall length and width for the face shield were determined from a store-bought and non-3D printed face shield. Using these dimensions and using a height of 1" for the base of the face shield the model shown in **Figure 7a** was created.

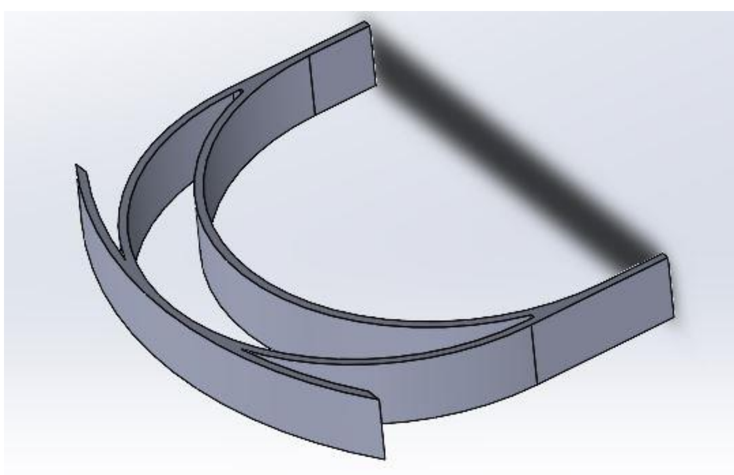


Figure 7a Initial base model design

This initial base model resembles store-bought face shields in its overall geometry but to be suitable for Dr. Pavlick's needs, several adjustments had to be made. First, a way to attach the physical shield to the base had to be created. Given that the shield material is flexible and can be hole punched, the simplest method for attachment was to add circular knobs to the front piece of the base that were slightly smaller than 0.25" as shown in **Figure 7b**. Since these knobs are slightly smaller than 0.25", a quarter-inch hole in the shield material should fit snuggly each of these and make attachment to the shield band simple.

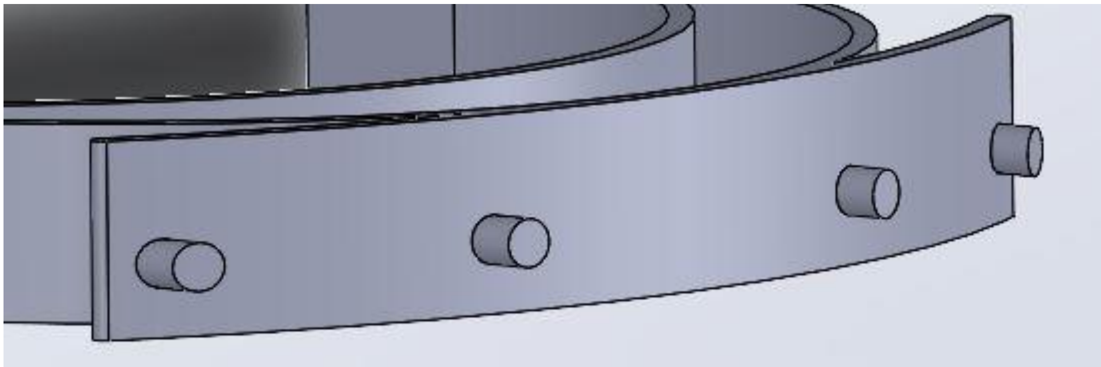


Figure 7b Shield attachment site

Another part of the design that had to be added was how to wear the face shield. For this oval-shaped extrusions were added to the back sides of the shield band so that a headband could be tied and attached to each side, allowing the face shield to be worn as shown in **Figure 7c**.

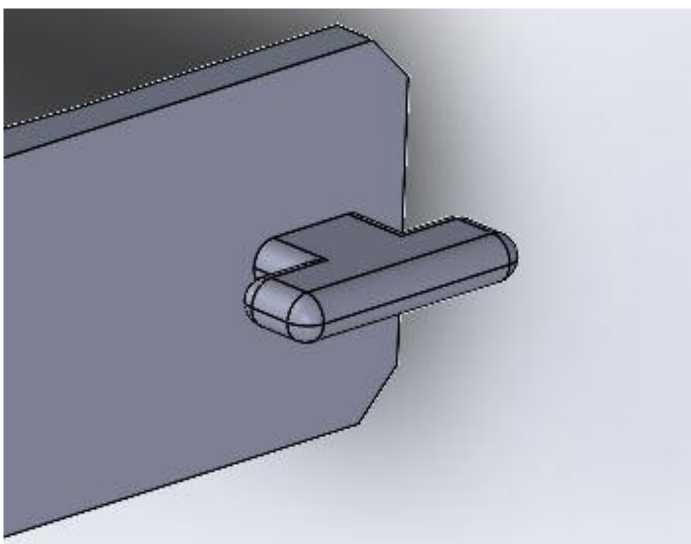


Figure 7c Head band attachment site

Currently, for the design, there is no room for Dr. Pavlick to attach his clip-on dental light to the face shield. To account for this, part of the front band was extruded upwards an extra inch to allow for the small room needed to attach the clip-on light as shown in **Figure 7d**. Using Dr. Pavlick's already working clip-on light was the simplest and most cost-effective way to tackle the lighting requirement for the design.

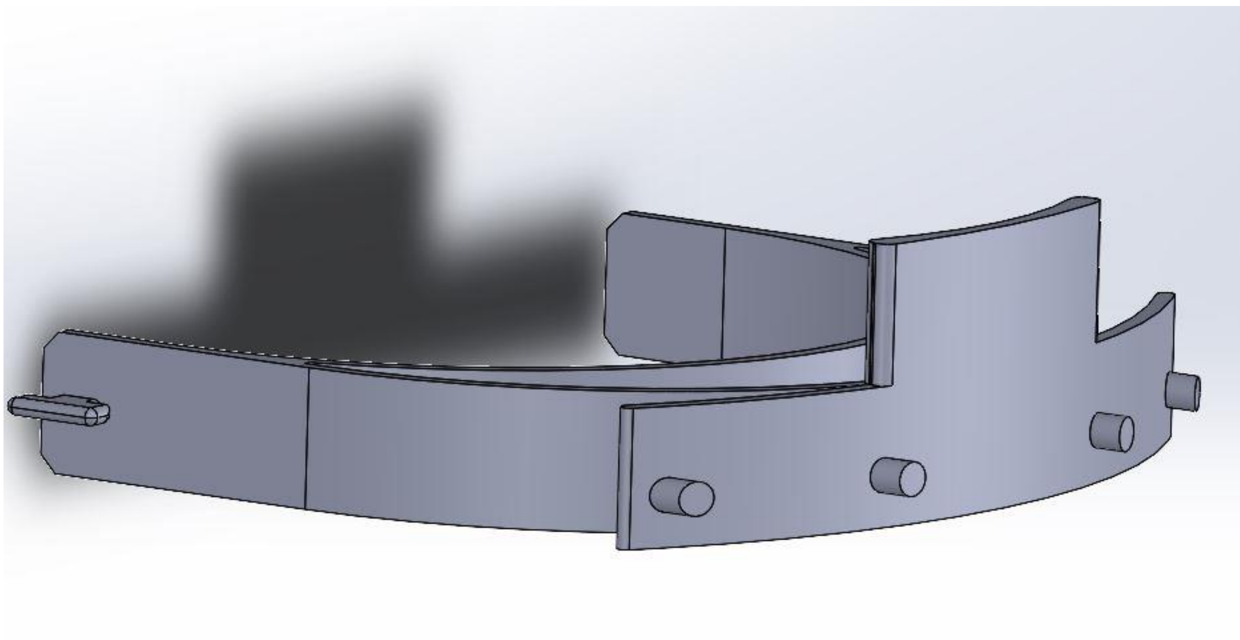


Figure 7d Clip on light attachment site

The most complicated part of the shield band design was undoubtedly the magnification aspect. It was desired that a 2-3X magnification be utilized. Before attempting this part of the design there were a few design constraints to be considered. First, the magnification device could not be too close to the patients; face as such it could make the patient uncomfortable and make it harder to Dr. Pavlick for operate. Second, the working distance had to be considered. Working distance is the distance from the front of the lens to the closest object where the object is in sharp focus. This is important as a blurry magnification image would it make very difficult for the user to perform detailed work. Most dental loupes have a working distance of 18" and this was used as the ideal working distance for the magnification purchase.

Unfortunately, the only magnification piece that was within the budget that could be purchased was a 2X magnification piece with a 10” working distance. This magnification piece is 1/8” thick. The simplest method of attaching the magnification piece was determined to be press fitting it, into the 3D printed part. Glue specifically for glasses could also be used to help keep the magnification piece in place. As shown in **Figure 7e**, a slot within the face shield with a width of slightly bigger than 1/8” is shown and will be used to press-fit the magnification piece.

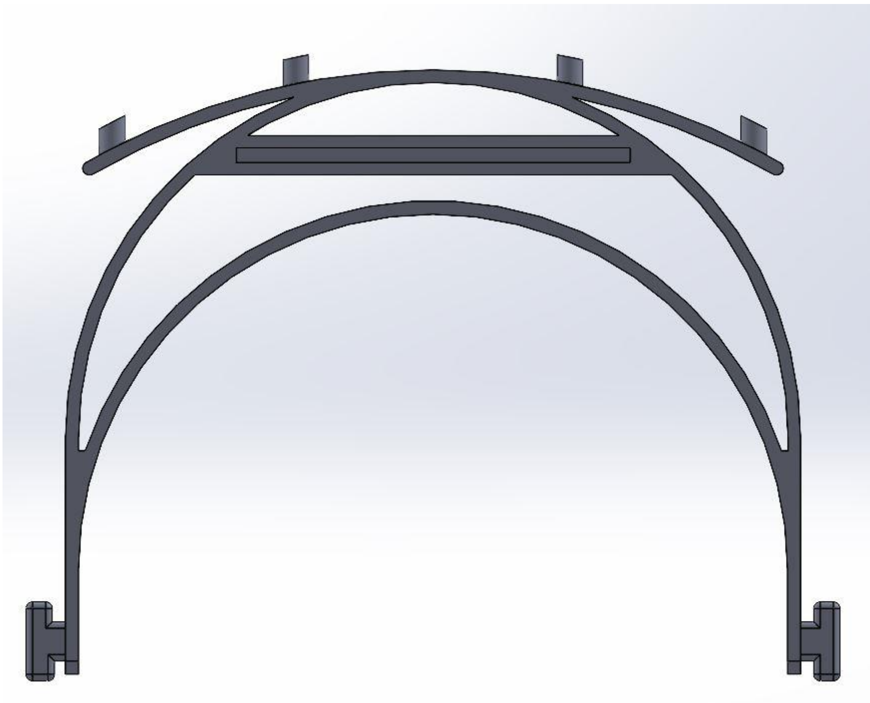


Figure 7e Magnification press fit site

3.2 Assembly Model

Part models were not available for the physical face shield, clip on light, foam padding and magnification piece. To account for this, rough models were made just to show how the parts would come together in the finished product. The assembly model is shown below in **Figure 8a-c.**

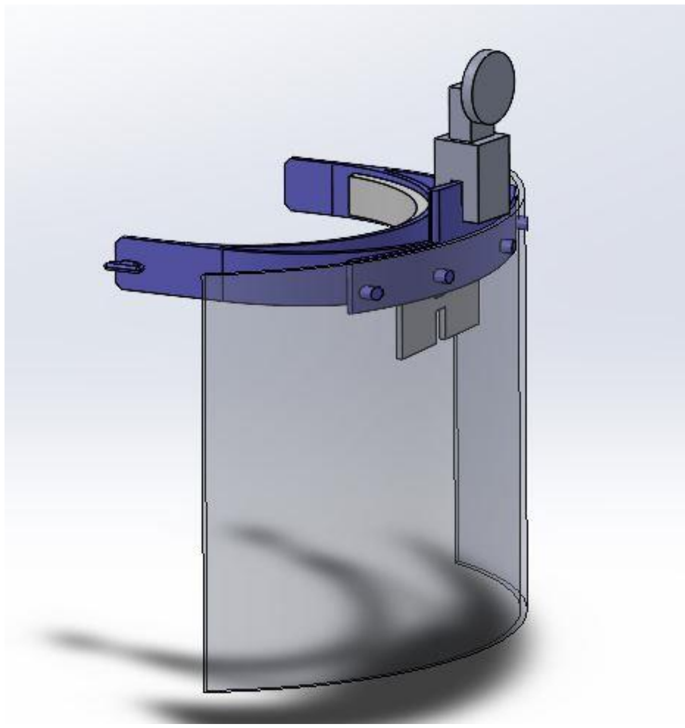


Figure 8a Iso view of assembly model

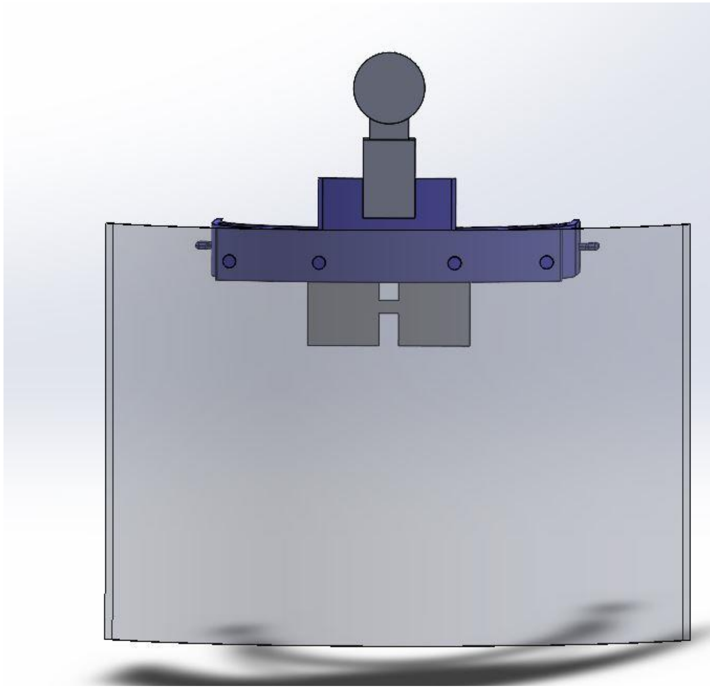


Figure 8b Front view of assembly model

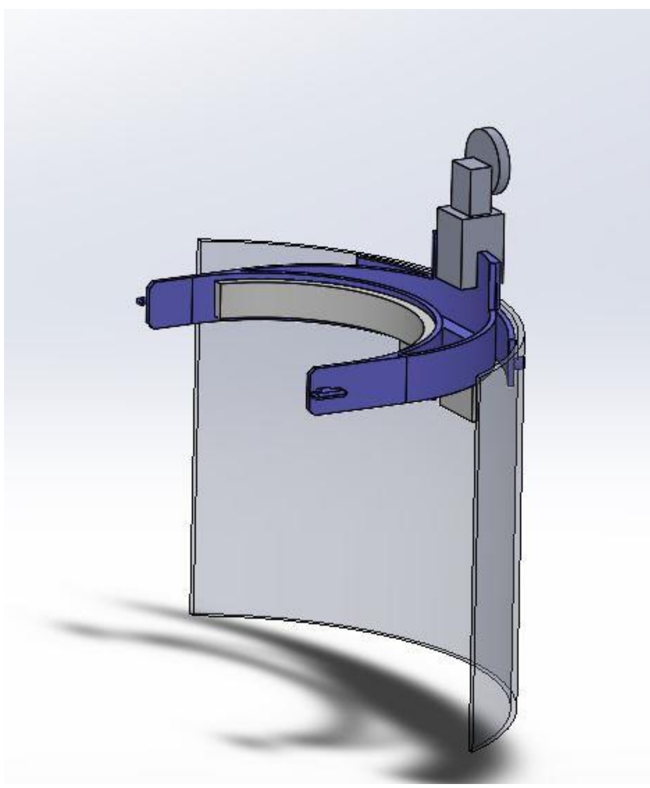


Figure 8c Back iso view of assembly model

3.3 Bill of Materials

Now with the part models and assembly model complete, a bill of materials was put together for the assembly model. The prices are based on online estimates.

Part	Cost
Clip on Light	0$ (owned by Dr. Pavlick)
Foam Padding	5$ (Joanne Fabrics)
Magnification	15$ (McMaster-Carr)
3D Printed Base	7$ (Akron Public Library)
Physical Face Shield	2$ (Amazon)
Head Band	0$ (owned from previous face shield)

Table 5 Bill of materials for face shield assembly

Excluding the cost of labor, the total price to build the face shield was about 30$. Given that dental loupes can cost hundreds of dollars, if the design works than this may be a cheaper alternative for dentists. Now with the design stage complete, manufacturing could begin.

4. Manufacturing

Due to the Covid-19 pandemic, manufacturing was more complicated than usual. The main problem being shipping delays and not actually meeting with Dr. Pavlick for the clip-on light portion of the final model. The magnification piece still arrived in time, the headband is already owned, and the polycarbonate shield did not come in so an old one was used. First, the 3D printed part will be looked at.

4.1 3D-Printing

For the 3D printing part of the project, the Akron Public Library 3D printers were used. The 3D printer used was a Robo R1+ and the only material was 1.75 PLA in various colors. The print fill used was the library's default. To 3D print at the library, an STL file of the Solidworks face shield base was created and then emailed to the library. The model was also oriented in such a way so that the least amount of material support was required. This orientation was with the flat surface starting as the bottom. After about 4 hours the 3D printed part was ready to be picked up.

The 3D print had support structure still attached to it when picked up so that was simply broken off. Unfortunately, the quality of the 3D print was not the best likely due to the 3D printer used, but the product still turned out decent. Pictures of the 3D printed part are shown in Figures 9a-d. The slot for the magnification piece turned out decent once the support structure inside was cleared out. Overall, the 3D printed part serves as a nice prototype, but for a final product, a smoother and cleaner 3D print would be desired.

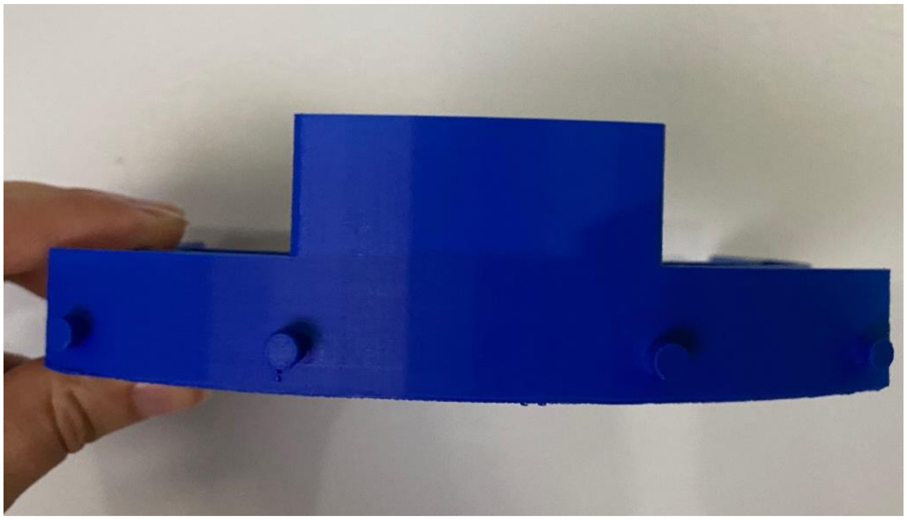


Figure 9a

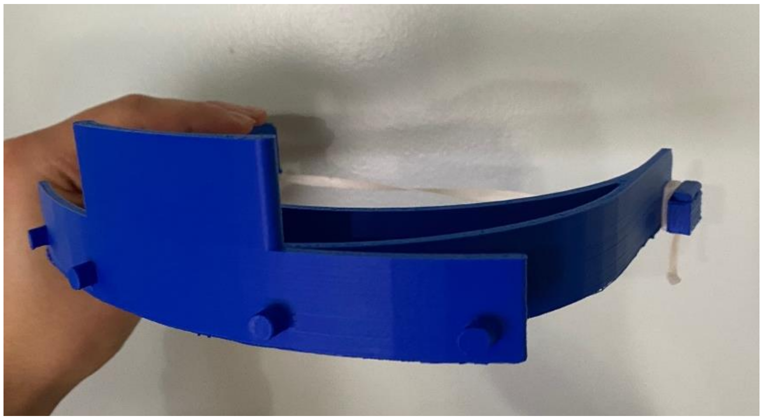


Figure 9b

Figure 9c

Figure 9d

4.2 Assembled Prototype

The assembled prototype does not include foam padding or the clip-on light since meeting with Dr. Pavlick did not occur due to the Covid-19 pandemic. The assembled prototype is shown in **Figure 10a/b**.

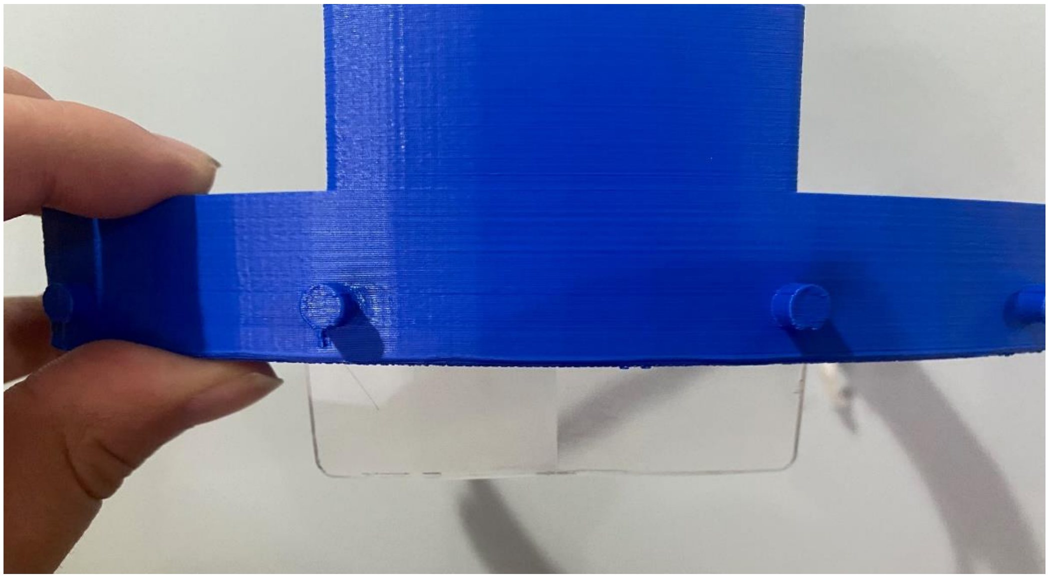


Figure 10a

Figure 10b

5. Future Improvements

This project attempted to create a face shield that incorporated lighting and magnification to meet a local dentist's needs from the Covid-19 pandemic. Although meeting with Dr. Pavlick was not possible due to safety concerns about the high level of community spread, some future improvements were still noted.

First, the face shield could be made to cover more of the face. While the shield provided adequate protection, the curvature of the base could be expanded to offer even more shielding. Second, the press-fitting into the slot did work, but some extra clearance had to be made. For future prototypes, it is recommended that the slot clearance be slightly larger. Additionally, the magnification piece was slightly above eye level causing the shield to have to be worn lower on the forehead. Adjusting the height of the slot would fix this problem. The main problem with the design is the working distance of the magnification. A working distance of 10" does not appear to be adequate. When trying to read something with the face shield on the object had to be fairly close to my face for the image to be clear. This could be changed by finding a magnification piece with a larger working distance; however, those magnification pieces are more expensive than my budget.

Overall, the face shield prototype provides adequate protection, would work with a clip-on light, and works for magnification of objects when close to the lens. Additionally, it was an excellent learning experience as I got to learn more about 3D printers, FDA approval for face shields, and was able to use the knowledge I have gained while at the University of Akron to attempt to design a new product.

6. References

Stephen F. Austin State University. *Introduction to Magnification*. faculty.sfasu.edu/munromicha/rhb493/magnify.html.

United States, Food and Drug Administration, Hinton, Denise M. *Emergency Use Authorization*, Insufficient Supply and Availability of Face Shields, 2020, pp. 1–6.

3D Insider. “16 Types of 3D Printer Filaments.” *3D Insider*, 4 Apr. 2019, 3dinsider.com/3d-printing-materials/.

Spring, Kenneth R. “Working Distance and Parfocal Length.” *Nikon's MicroscopyU*, www.microscopyu.com/microscopy-basics/working-distance-and-parfocal-length.