



Win-Shield Medical Devices' Capstone Project Report

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EXECUTIVE SUMMARY

This project creates a multipurpose device that protects healthcare workers from liquids and flying fragments, providing whole user safety. Existing face shields are uncomfortable and fail to protect the entire cranium from bodily fluids, while disposable ones are not environmentally or economically viable. The device developed is adjustable, comfortable, reusable, and easy to use, withstanding necessary cleaning processes. It also allows the use of head-mounted tools and devices.

The proposed solution is called the Flip Shield. It includes a head shield, face shield, and hinge mechanism designed to protect against bodily fluid sprays, particularly from coughing and sneezing. The head shield has a slightly enlarged brim, protrusions on either side for the hinge, and can act as a platform for accessory devices. The face shield is designed to mate with the brim of the head shield, a remodelled face shield, and protrusions on either side for the hinge. The hinge mechanism is comprised of two curved hinge slides and two attachment pieces. The attachment pieces move inside the hinge slide, this ensures the head and face shield remain connected while allowing the face shield to move up freely. A prototype was 3D printed using polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS) filaments, but production-grade parts will be constructed using polycarbonate and expensive, high-quality, water-cooled tool steel injection molds.

The Flip Shield was evaluated based on the set-out verification/validation criteria, cleaning test methodology, and evaluation results, including an easy-to-use design, a locking hinge, reusability, simple assembly and disassembly, the time it takes to put the device on, and weight. Cleaning methodology was also tested, including disinfectant wipes and bleach solution method. Durability methodology was evaluated by performing the durability test, which aimed to evaluate the resilience of the hinge mechanism during everyday usage. The assembly and disassembly test were conducted to assess the duration and ease of each process. Both disinfectant wipes and bleach solution were found to be effective cleaning methods. Assembly took 1 minute and 10 seconds, disassembly took 32 seconds, and the durability test revealed that the PLA material used for the hinge mechanism caused the device to fail after approximately 100 cycles.

The attachment method, material selection, and hinge channel design of the face shield can be improved to enhance its functionality and user-friendliness. Using a stronger material for better attachment and manufacturing through injection molding can result in a higher-grade and longer-lasting design. The cleaning method can be improved by combining the bleach solution and disinfectant wipes. Improving the push button design and modifying the finger tabs for better ergonomics can also enhance the design. A clear and transparent pet sheet with no ripples is crucial for clear vision, and a short user manual with engravings on the design body can guide users for easy installation of the hinge pieces.

The final design solution for the face shield project satisfies all the requirements, including creating an adjustable and comfortable shield, providing space for device mounting, making it reusable, and adhesive-free for easy cleaning and maintenance. The shield is made from durable and high-quality materials, making it cost-effective and eco-friendly. The final design solution is a reliable and effective tool suitable for various users.

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1 INTRODUCTION

1.1 Purpose

Healthcare workers are currently using sub-optimal shields to protect their eyes, nose, mouth, and head from splashing and spraying liquids, explosive bodily fluids, and flying fragments. Typically, these devices fall short of offering whole user safety, such as protecting the entire cranium (head and face) against bodily fluids that come from sneezing and coughing. Most face shields utilized in clinics, hospitals, and healthcare facilities are either uncomfortable to wear all day long or healthcare workers see no purpose in having to use one. The purpose of this project is to create a reusable, multipurpose device that protects the head and face of individuals in the healthcare industry while also giving the user access to an array of head-mounted tools and devices to use while they are on the job.

1.2 Background

The COVID-19 pandemic brought great demands and shortages of face shields and masks to protect people against the novel virus. Due to the great demand for personal protective equipment (PPE), there were very few protective face shields at the beginning of the pandemic. Some scarcely available face shields were too heavy and not intended for medical use, and some shields that were more suitable for clinical use did not offer full and adequate protection. During the pandemic, the shortage and inadequacy of facial protection devices were solved by Win-Shield Medical Devices. They quickly developed and manufactured a shield that encapsulated a user's head and faces from the bodily spray. This is device was named the C-Shield (COVID Shield).

1.2.1 Existing designs

An example of a heavier, non-medical face shield is shown in Figure 1. These devices were used by some people due to the supply-chain shortages of proper medical PPE. However, these face shields were not perfect barriers for resisting transmission and splashes, and they were too uncomfortable for daily use. It should also be mentioned that this face shield, like most face shields, does not protect against airborne viruses and particulates that need to be filtered and removed from the air; face masks are responsible for filtering airborne particles.



Figure 1: Example of an industrial face shield (Sealey 2022).

Another face shield that was sometimes found during the pandemic was generic as seen in Figure 2. This shield was designed to be disposable, meaning it lacked reusability factors, and it also did not protect the top of a user's head from biological splatters. While the use of disposable plastics is impactful environmentally and economically, the pandemic warranted the use of these cheap, easy to manufacture shields. Moving forward, reusable PPE, including face shields, needs to be developed and integrated into the medical industry to limit the environmental and economic tolls of one-time use devices.



Figure 2: Example of a generic face shield used during the pandemic to protect healthcare professionals (JNBS 2022).

1.2.2 The C-Shield

Win-Shield Medical Devices introduced the C-Shield into the market during the pandemic to help meet the vast demand for PPE (see Figure 3). The C-Shield was a significant improvement to existing shields. It protected against more splatter and splashes as compared to the other shields on the market as it covered the top of the head and the face. While the C-Shield was lightweight and completely encapsulated the head and face, it still lacked reusability and the ability for the user to quickly move the face shield portion out of the way. Some healthcare workers have knocked the C-Shield off their heads when they performed tasks like CPR (cardiopulmonary resuscitation) which requires looking down towards the patient with their chin at their chest. The C-Shield also trapped some excess body heat around the user's head, which became an annoying inconvenience since the users began sweating and quickly became uncomfortable. A device that includes a moveable face shield, is comfortable, and delivers the same protection as the C-Shield is in dire need. The key areas of concern for a new device would be comfort, weight, and ease of use and assembly.



Figure 3: Win-Shield Medical Devices' C-Shield (Win-Shield 2022).

1.2.3 Next-Gen Shield

After Win-Shield released their C-Shield they received feedback for improvements from the healthcare community. With this feedback, Win-Shield developed an updated version of the C-Shield called the Next-Gen Shield. The Next-Gen Shield is pictured in Figure 4.



Figure 4: A 3D model of Win-Shield Medical Devices' Next-Gen Shield.

1.2.4 Cleaning and reusability

Having clean PPE is important so medical staff and patients are not put at an even greater risk contracting diseases or being exposed cross-contamination. Throughout the pandemic, many ordinarily disposable personal protective devices were simply cleaned off and reused, due to the PPE shortages. Face shields were sometimes wiped clean with disinfecting wipes or washed by the medical device reprocessing (MDR) unit at some hospitals for one minute at 90°C, before being reused. However, over time these face shields suffered wear and deformed due to the cleaning processes. A reusable face shield must stand up to these cleaning processes better than the disposable equipment to be classified as reusable.

1.3 Problem Definition

This project is aimed at solving some of the problems that the C-Shield has not fully addressed and making improvements to the protection rate from hazardous substances. The device will protect a user's face, head and should have an adjustable face shield that can be moved out of the way when needed. This device should have the additional capability of mounting an array of devices on top of the head. These devices may include magnifying lenses, a camera, and lights.

Unlike other protective devices in the medical industry, one of the most prominent features that will differentiate our product will be its ability to be cleaned and reused.

1.3.1 Problem statement

Many face shields on the market today only provide protection of the face instead of a complete protection of the face and head from liquid splatter. This is a major concern because splashes to the head will still cause occupational-related infections. An alternative solution must be developed for clinicians that provides a protective and practical cover from biological and other hazards when performing medical procedures.

1.3.2 Design requirements

From discussions with the client and research into the problem, design requirements including the required functions, objectives, and constraints were noted and amalgamated into Table 1.

Table 1: Design Requirements

Functions	Objectives	Constraints
<ul style="list-style-type: none"> • To protect and cover the face and head from liquid splatter • Hold other applicable devices on the face and head shield 	Reusable > 20 uses (days)	Reusable > 15 uses (days)
	Assembly time (building device) < 1 minute	Assembly time (building device) < 2 minutes
	Disassembly time < 1 minute	Disassembly time > 1 minute
	Device operated by one hand	Device operated by two hands
	Meet requirements for CSA Z94.3:20 and ISO 16321-1:2021 (protects face and head from direct biological and chemical splatter (e.g., blood, sneezing, coughing, dust))	
	Health Canada Class I medical device (the device poses the least possible risk to the user)	
	Modular device, containing 3 parts: face shield, head shield, and hinge	
	Clear, anti-fog face shield material	
	Device to maintain the same or similar physical outline as the C-Shield	

2 PROPOSED SOLUTION

2.1 Main Components

The proposed solution, the Flip Shield, encompasses: (1) a head shield, (2) a face shield, and (3) a hinge, as shown in Figure 5. The head and face shield were extracted from the Next-Gen Shield (see Figure 4). The Next-Gen Shield was sliced in half and some minor modifications were made to both the head shield and the face shield. Modifications to the head shield include a slightly enlarged brim and a protrusion on each side of the shield for the hinge. Modifications to the face shield include an enlarged surface for mating with the brim of the head shield, a remodelled face shield, and a protrusion on each side of the face shield for the hinge.

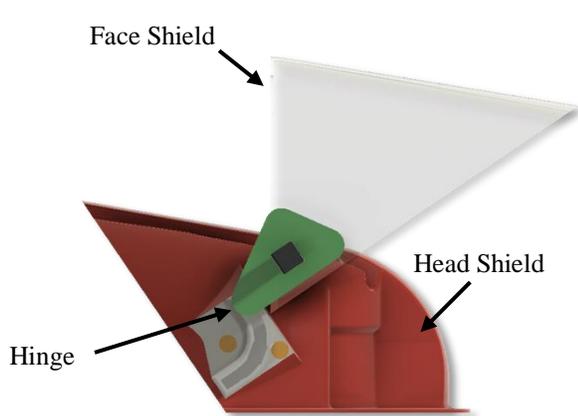


Figure 5: Side view of the Flip Shield 3D model.

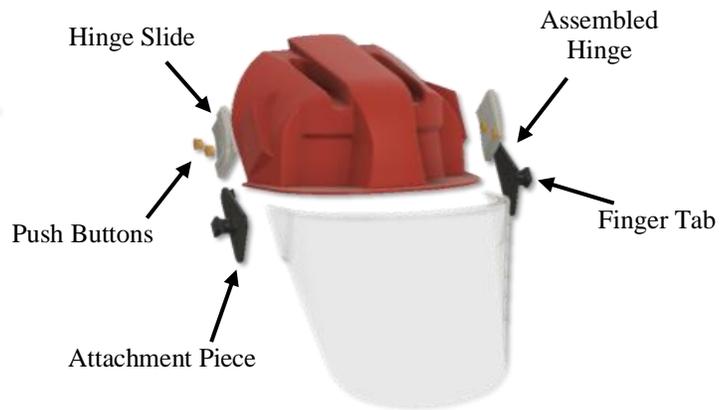


Figure 6: An exploded image of the Flip Shield with the hinge parts labelled.

2.1.1 Head shield

The primary purpose of the head shield is to protect the head from bodily fluid spray (from coughs and sneezes). The head shield's secondary purpose involves attaching the face shield to the user's head via the hinge mechanism. The hinge slides are attached directly to the head shield using push buttons and the face shield attachment pieces connect the face shield to the hinge slides. Figure 6 better explains the face shield attachment method. The head shield's auxiliary purpose is to act as a platform for accessory devices such as magnifying lenses, lights, and/or camera(s), as shown in Figure 7 and Figure 8.

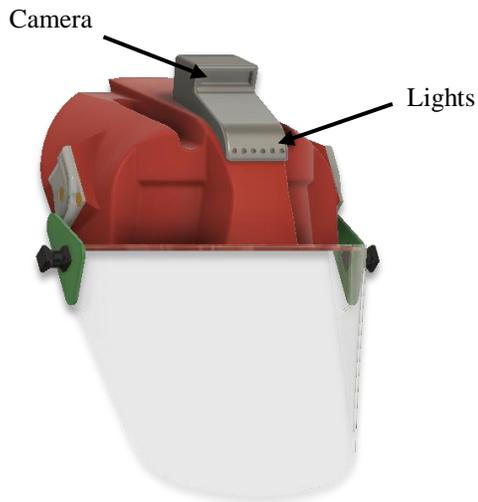


Figure 7: A 3D model of the Flip Shield with a conceptual camera and light system mounted on top.



Figure 8: The 3D printed Flip Shield prototype with the mock up device mounted on top.

During the prototyping process, a 1.8 mm thick shell of the head shield was 3D printed using polylactic acid (PLA) filament. An image of the print can be seen in Figure 9. PLA filament was used since it's easy to print with and was available; however, PLA is not resistant to high temperatures. A more suitable material for manufacturing would be polycarbonate (PC). PC is more durable and more heat resistant than PLA; polycarbonate has a maximum continuous use temperature of 125°C (BPF 2023a). The production grade PC head shield would either be injection molded or vacuum formed using expensive, high-quality, water-cooled tool steel molds. Due to the high cost associated with creating tool molds, production grade parts were not constructed during this project.



Figure 9: 3D printed head shield.

2.1.2 Face shield

The face shield's sole purpose is to act as a facial barrier against bodily fluid and other liquid sprays. The attachment pieces for the hinge are attached to either side of the face shield (Figure 10).

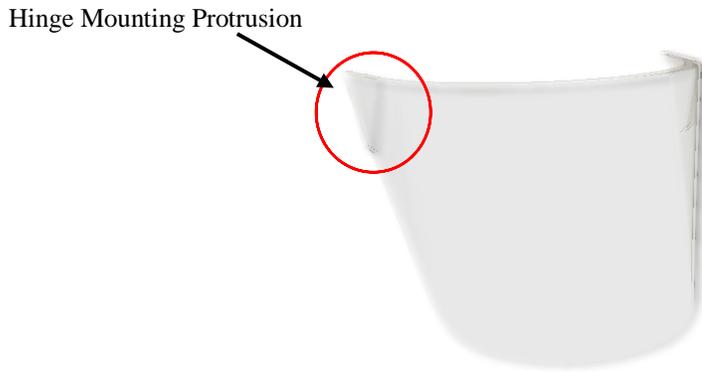


Figure 10: The 3D model of the face shield with one of the attachment piece protrusions highlighted.

The prototype face shield was also 3D printed using PLA filament, as shown in Figure 11. After 3D printing a solid face shield, a hole for looking through was cut out of the PLA part and a clear, thin sheet of plastic from a generic face shield was glued to the PLA frame. An image of the final prototype can be seen in Figure 12.



Figure 11: An image of the 3D printed Flip Shield in the closed position.



Figure 12: An image of the Flip Shield in the open position.

2.1.3 Hinge

The hinge mechanism features a distinctive circular channel that distinguishes it from conventional hinge systems. It has protrusions at the ends of its channel that act as a locking system when the face shield is open and closed. Since the circular channel is angled, along with the face shield slider, to keep the attachment slider from coming loose, a cut out in the middle of the arc allows the face shield slider to be easily inserted into the slider. Figure 13 clearly shows the hinge and its distinct features.

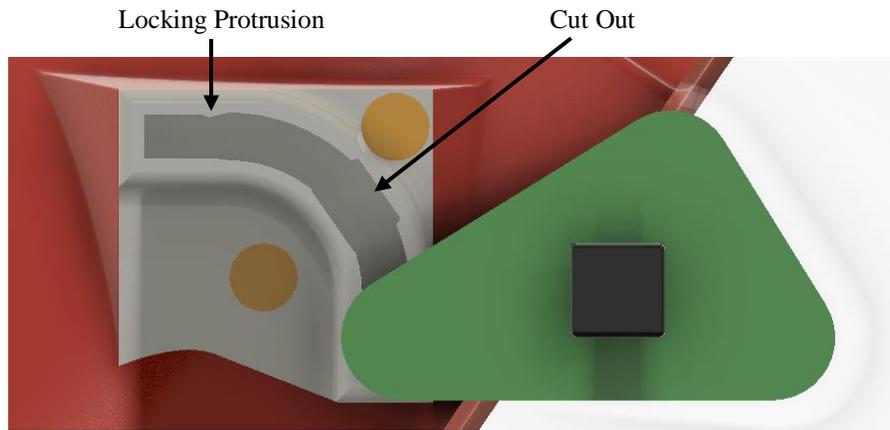


Figure 13: A close-up image of the hinge attached to the Flip Shield.

The primary purpose of the circular hinge is to connect the head and face shield together while allowing the face shield to move up freely. The circular hinge mechanism is also designed to provide clearance for devices to be mounted on top of the head shield. The circular hinge mechanism is comprised of two circular channels (Figure 14), two attachment pieces (Figure 15) and two finger tabs on the attachment pieces (Figure 16).



Figure 14: Circular channel

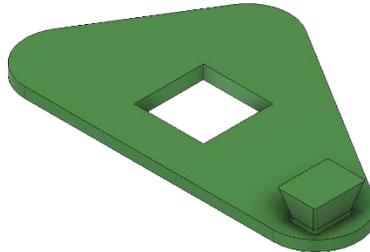


Figure 15: Attachment piece



Figure 16: Finger tab

During the prototyping process, the hinge mechanism was 3D printed using both acrylonitrile butadiene styrene (ABS) and PLA filament. The final prototype can be partially seen in Figure 12.

2.2 Distinctive Features

The Flip Shield has several distinctive features that allow it to be an effective, productive, and lightweight device. The distinctive features include:

Open Freely: The face shield can open freely if the user desires. If the user wants to put the face shield up anytime, they can just hold the finger tabs from both sides and lift the face shield up just by moving up the hinge channel.

Device Mounting: Devices can be mounted on top of the head shield. The user can also lift the face shield up without the face shield interfering with the devices mounted at the top. Some devices that can be mounted include lights, cameras, and magnifying glasses.

Lockable Position: The face shield can lock at both the top and bottom of the hinge channel. This feature allows the face shield to stay at the top without falling, giving the user the space and scope to carry out actions that require interactions with their faces when desired (i.e., drinking

water). The face shield can also be locked at the bottom and prevent liquid splatter from getting in.

Reusable and Lightweight: The device is lightweight and can be reused after prolonged hours of usage. After usage the user can clean the device using bleach solution and the device is ready to be reused. The material is made up of a thickness that is lightweight and suitable for reusing.

Zero Adhesives: Adhesives like glue or tape are hard to clean and become less effective after being cleaned. The Flip Shield has solved this problem with the help of small push buttons that secure the hinge channel on to the head shield. The user aligns the hinge on the head shield and places the push buttons through the holes. To lock the hinge channel, the inside button is pressed into the push button, as shown in Figure 17 and Figure 18.

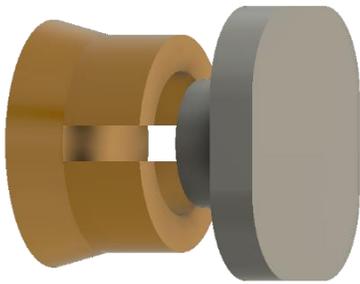


Figure 17: Push buttons separated.

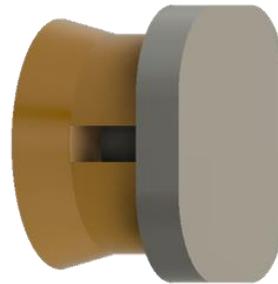


Figure 18: Push buttons pressed together.

Finger Tabs: The hinge attachment slider has finger tabs installed on its sides so that the user can use those to travel up the hinge channel. These were introduced to give the design a more ergonomic feel and help the Flip Shield be more user friendly. Holding the finger tabs and moving along the hinge channel makes the lifting and putting the face shield down an easier operation.

Body Extrusions: The extrusions on the head shield and face shield make it easier for the user to navigate on where to place the hinge pieces and hinge attachment sliders. These extrusions on the sides of the body ensures hinges are always parallel with each other and helps the user with aligning the hinge parts.

Modular Design: The entire Flip Shield is made to break down into its basic parts for easy cleaning and part replacement. This modular design aids in the factor of easy manufacturing of the product as well.

Ecosystem Integration: The Flip Shield is designed to fit into Win-Shield Devices' product ecosystem. The company is developing a wide range of products and the key feature in their manufacturing process is that all their designs can be used with one another. The Flip Shield could be easily incorporated into one of their most prominent device ecosystems

2.3 Design Operation

Owing to the modular design of the Flip Shield, a comprehensive instruction manual is required to facilitate the assembly and disassembly of the device. The Flip Shield is composed of the head shield, face shield, hinge mechanism, and two sets of push buttons, namely, two circular buttons and one half-circular button with a circular one. Below are detailed instructions on how to assemble, disassemble, and operate the Flip shield.

2.3.1 Assembly

1. Take the hinge channel and place it over the holes located on the side of the head shield.
2. Make sure that the bottom part of the hinge (which has a curved shape) is aligned with the bottom part of the enlarged brim (which also has a curved shape).
3. Insert the circular push buttons from both sides into the middle hole on the head shield.
4. Insert the half-circular push button from the inside of the corner hole and the circular one from the outside, ensuring that the flat part of the button is aligned with the flat part of the inside head shield.
5. Apply gentle pressure until the push button is secure and the pieces are attached together.
6. Slide the face shield attachment slider into the hinge channel, which can be accessed through a cut-out in the middle of the hinge.

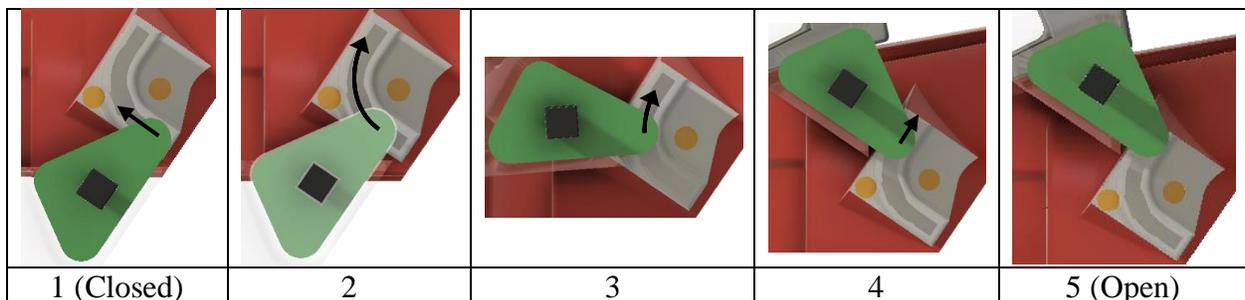
2.3.2 Disassembly

1. Slide the face attachment slider out of the hinge channel by pulling it through the cut-out in the middle of the hinge.
2. Find a flat object (like a screwdriver) that you can use to remove the push buttons from the holes.
3. Insert the flat object into the gap between the push button and the shield, then gently pry the button out of its hole. Repeat for all push buttons.
4. Remove the hinge mechanism from the head shield by pulling it away from the shield.

2.3.3 Operation

1. To unlock the face shield, push the finger tabs upwards on the face shield.
2. Move the finger tabs up the hinge channel until they click into place at the top (open position).
3. To close the flip shield, slightly push down on the finger tabs to unlock the face shield.
4. Move the finger tabs down the hinge channel until they click into place at the bottom.
5. See Table 2 for more details.

Table 2: Operation steps



3 EVALUATION PROCEDURE AND RESULTS

To verify that the project objectives have been met and that the end user's needs have been satisfied, a set of evaluation protocols were established and assessed. Table 3 presents the design evaluation for the Flip Shield, including the design objectives, test procedures, evaluation, criteria, and results.

Table 3: Evaluation Procedure and Results

Design Objectives	Test Procedures	Evaluation	Criteria	Results
Reusable	See Section 3.1 Cleaning Methodology	- If method cleans all soil hinge parts - If cleaning chemicals react with material	Pass: - Parts are cleaned thoroughly -Materials does not react with cleaning agents Fail: - Parts are not cleaned -Material reacts with cleaning agents	- Parts were thoroughly cleaned -Bleach solution did not react with material -Disinfectant wipes discoloured hinge material
	See Section 3.3 Durability Methodology	Number of cycles before hinge failure.	Pass: Cycles till hinge failure (days) > 15 Fail: Cycles till hinge failure (days) < 15	-Cycles till hinge failure = 100 (10 days) due to it being a prototype.
Assembly time	See Section 3.4 Assembly and Disassembly time	Time it takes to assemble the device.	Pass: Assembly time < 2 minutes. Fail: Assembly time > 2 minutes.	Assembly time = 1 minute 20 seconds.
Disassembly time	See Section 3.4 Assembly and Disassembly time	Time it takes to disassemble the device.	Pass: Disassembly time < 1 minute Fail: Disassembly time > 1 minute	Disassembly time = 32 seconds.
Device operation	- Unlock the face shield by applying force in the middle of the face shield. - Unlock the face shield by pushing the finger tabs upwards using both hands.	Usability	Pass: Device operated using one hand. Fail: Device cannot be operated using two hands.	Device can be operated using two hands easily.

Strength test	See Section 3.5 Strength Test	Force required to remove the hinge from the head shield.	Pass: Required force > 15 Newton Fail: Required force < 15 Newton	- Maximum force needed = 51 Newton - Minimum force needed = 21 Newton
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3.1 Cleaning Methodology

The Flip shield is to be cleaned by testing two cleaning methods for their efficiency: cleaning using disinfecting wipes and cleaning using a bleach solution; and their efficiency.

3.1.1 Disinfectant wipes method

The first method is cleaning using disinfectant wipes. The disinfection process follows medical industry standards as per Shared Health Manitoba disinfecting procedures using accelerated hydrogen peroxide or intervention wipes. The cleaning methodology described below is specific to the hinge part of the shield and does not include the full shield cleaning procedure.

1. Use 5 disinfectant wipes in total. Start with the inside of the hinge parts.
 - a. With 1st disinfectant wipe, hold the outside of the pieces.
 - b. With 2nd disinfectant wipe, clean/disinfect the inside by thoroughly wiping the inside of the hinge parts and into the inside of the grooved parts.
2. Clean/disinfect the outside of the hinge parts.
 - a. With 3rd disinfectant wipe hold the inside of the hinge parts.
 - b. With 4th wipe clean thoroughly the outside of the hinge parts.
 - c. With 5th disinfectant wipe, clean/disinfect the flat surface to have the hinge parts dry.
 - d. Place the hinge pieces onto the surface. Allow air drying of all the parts.
 - e. While the parts are air-drying, discard used wipes then perform hand hygiene.

3.1.2 Bleach solution method

The second cleaning method involves soaking the parts of the shield in a mixture of 50:1 – water to bleach for 10 mins before each use. Soap and water are used to clean the device if there is any debris.

1. Make a solution of water and bleach; 50:1, respectively.
2. Soak the hinge parts in solution for 10 minutes.
3. Air dry the parts.

The face shield is assessed after the week of being in use and undergoing cleaning after each use or before use by another individual to test if it can withstand the cleaning processes by taking note of any film formations or scratches from the cleaning procedures.

3.2 Cleaning Results

The face shield is assessed after the week of being in use and undergoing cleaning after each use or before use by another individual to test if it can withstand the cleaning processes by taking note of any film formations or scratches from the cleaning procedures.

3.2.1 Disinfectant wipes method

- The wipes cleaned the hinge parts successfully.
- After about 10 times of cleaning the black hinge parts had some parts that were losing the shiny/lustiness of the material.
- The wipes are easy to handle.

3.2.2 Bleach solution method

- The methods cleaned the hinge parts successfully.
- If parts are overly soiled in the grooves and corners the solution needed extra help of using wipes to get into the corners.
- The material maintained its lustiness after 10 times of being cleaned.

3.3 Durability Methodology

The principal aim of the durability test is to evaluate the resilience of the hinge mechanism during everyday usage. To execute this assessment, a designated team member was responsible for operating the device by moving the hinge mechanism at least ten times per day. In each cycle, the face shield was maneuvered up and down the hinge channel and locked in both the open and closed positions. The durability test was performed until the hinge channel eventually failed.

3.3.1 Results

After undergoing approximately 100 cycles, corresponding to 10 days of usage, the hinge mechanism failed to secure the face shield in an open position. The protrusions located at the end of each channel, which serve as locking mechanisms for the open and closed positions, had become worn off, causing difficulties in maintaining the face shield in an open position. This issue is ascribed to the utilization of PLA material for the 3D-printed hinge mechanism.

3.1 Assembly and Disassembly Test

The purpose of conducting the assembly and disassembly test was to assess the duration and ease of each process. To accomplish this objective, four groups, including a 13-year-old girl, a 24-year-old, a 27-year-old, and an 85-year-old senior, were recruited to perform the tests. Each group was instructed to assemble and disassemble the Flip Shield three times, following the instructions provided in the Design Operation section. The time taken for each trial was recorded and averaged to obtain the most precise outcome.

3.1.1 Results

After completing the tests, the Flip Shield was put together in an average time of 1 minute and 10 seconds and taken apart in an average time of 32 seconds. The design specifications are met by these times.

3.2 Strength Test

The objective of the strength test is to evaluate the reality of how much force is required to take the hinge off the head shield while the push buttons are in place. To conduct this test, a test sample was made.

The test sample consisted of a flat piece of plastic surface that will represent the head shield hinge attachment region along with the hinge piece and the push buttons. A small hole is drilled on the surface of the hinge and the flat plastic piece so that the test frame can apply pressure on that region by the help of an adapter. Four wooden blocks are also placed on the bottom surface of the test sample so that it can sit on the test frame and have some height as well so that the detachment of the hinge can be understood.

Next, the hinge piece was placed aligning along the holes present on the head shield holes. The push buttons were inserted from both sides so that the pieces are attached together. A bit of extra force was applied on the push buttons while pressing to make sure it is tight enough to hold the hinge piece in place.

The test sample is then placed on the test frame and the drilled hole is aligned under the adapter attached to the load cell. Pressure is then applied on the test sample by the test frame at a rate of 15mm/min. Pressure is applied until the hinge piece detaches itself from the plastic piece. This action is sought to represent the situation where the push buttons are unable to hold the hinge pieces together after adequate tension force is applied. The test was conducted 3 times using 3 different samples of push buttons. The results were different in 3 cases. But however, an average number was found.

1. Test 1: The results of the first test were that a force of **42** Newton of force was needed to detach the hinge pieces off the flat plastic surface.
2. Test 2: The results of the second test were that a force of **21** Newton of force was needed to detach the hinge pieces off the flat plastic surface.
3. Test 3: The results of the third test were that a force of **51** Newton of force was needed to detach the hinge pieces off the flat plastic surface.

It is found that a minimum of **21 Newton force and a maximum of 51 Newton** force is needed to completely detach the hinge piece off. The effect of what the material is manufactured with plays a vital role in this test. The push buttons used in this test were made with the help of 3d printing. Also, the pressure angles on the push buttons have an impact on the result. The pressure angles were set at 10 degrees for the samples that were used in the test. The strength will differ when this number is altered as well. If the prototype was developed with a stronger and more reliable material the numbers are expected to move up, as the design will get stronger and sturdier.

4 LIMITATIONS

The development of the Flip Shield faced several limitations that impacted the final product. These limitations are categorized into three sections: design solutions, test methodology and results.

4.1 Design Solutions

Due to budget constraints, time limitations, and lack of access to industrial quality workshops, it was not possible to create a production-grade prototype. This made it difficult to determine the final weight of the design, which will depend heavily on the materials used for manufacturing. Additionally, the design was tailored to mount specific devices provided by the client. This made it difficult to modify the design for other devices that have different dimensions. Modifications to the flip shield to enable one-hand operation was not possible due to time constraints and manufacturing resources.

4.2 Test Methodology

The strength of the push buttons could not be tested to their full potential as the ones used for the test were manufactured using 3D printing and were not made from high-grade material. This caused the test to provide results with a slight marginal difference. Additionally, it was mentioned that the design would be able to integrate with future products such as the Powered Air Purifying Respirator currently being developed by Win-Shield, but no testing could be performed as the system is still under development.

4.3 Results

Disinfectant wipes have been found to alter the color of materials after multiple cleaning rounds, indicating that they do not contribute to the longevity of the material. The reason for this is that disinfectant wipes contain stronger chemicals that cause discoloration of the material. Furthermore, the bleach solution method is not always effective in cleaning the grooved parts of hinges. This is because the chemicals in bleach are not as potent as those present in disinfectant wipes.

5 RECOMMENDATIONS

Based on the feedback received, results attained during the testing and evaluation phase of the flip shield, several areas were identified where improvements can be made to enhance the overall functionality and user experience. These improvements are aimed at optimizing the attachment method, manufacturing process, cleaning methods, and user instructions to make the design more user-friendly, durable, and effective for medical settings. These recommendations are as follows:

- Improvement of the attachment method could be made by making further modifications to the push buttons and the hinge itself. This relies on the aspect of what material is used to build the design as a whole. A stronger material such as polycarbonate will result in better attachment in general.

- Selection of proper high material is recommended for manufacturing. Injection moulding is a good option when considering mass production of the design. This will result in producing a higher-grade design that can last longer.
- The cleaning methods could create better results if used together, using the bleach solution method as the primary method, and using the disinfectant wipes as additional cleaning is needed.
- Improvement of the hinge channel design to make it more user friendly is also suggested. Various users depending on their age groups may face trouble travelling along the hinge channel. Modification can be made so that it provides a better user experience.
- Improve the push button design so that it can attach the hinge in a better manner. The pressure angles in the push button have an impact on the overall attachment and strength of the attachment. Also developing the push buttons with higher grade material can result in better functionality.
- For manufacturability, prepare high grade moulds of the face shield so that the pet sheet is clear and transparent and ripple free after thermoforming. Developing with poor material will leave off ripples on the face shield and will eventually result in poor vision. As the design is sought to be used in medical settings, the aspect of clear vision is more than important.
- Developing a short user manual is also suggested as someone new may find it difficult to assemble the design. Minor engravings on the design body can also be made, if possible, to guide the user for easy installation of the hinge pieces.

6 CONCLUSION

The final design solution successfully addresses the requirements set forth for the project. One of the primary requirements was to create a clear face shield that is adjustable to fit the needs of the user. The design team was able to achieve this by incorporating a mechanism that allows the face shield to be moved up or down, depending on the user's preference. This feature ensures that the face shield is comfortable and provides optimal protection without restricting the user's movement.

Another key requirement was to provide adequate space for devices to be mounted on top of the face shield. The design team was able to accomplish this by creating a dedicated mounting area on the top of the shield. This area allows the user to attach various devices, such as a headlamp or camera, without obstructing their view or compromising the functionality of the shield. The device also had to be reusable, and the final design solution satisfies this requirement as well. The face shield is made from durable and high-quality materials, which means it can be used multiple times without any loss of functionality or effectiveness. This feature is not only cost-effective but also eco-friendly, as it reduces the amount of waste produced by disposable face shields.

Finally, the design team created an adhesive-free device, which is a critical requirement for medical professionals and other users who require clean and hygienic equipment. Adhesives can be difficult to remove and may leave residue behind, which can compromise the effectiveness of the device. By eliminating adhesives from the design, the team has created a device that is easy

to clean, maintain, and reuse. Overall, the final design solution successfully meets all of the project's requirements and is a reliable and effective tool for a wide range of users.

7 REFERENCES

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8 APPENDIX

8.1 Bill of Materials

The bill of materials for the project can be found in Table 4. This table contains materials needed for prototyping the Flip Shield and the equipment used during the process. As the project and prototyping continues, more complete bill of materials will be composed.

Table 4: Bill of Materials (All costs in CAD)

Component	Qty	Description	Unit Cost	Bulk Unit Cost	Total	Total (bulk)	Distributor	Distributor P/N	Manufacturer	Manufacturer P/N
Closed-cell foam	2 pcs	1.5 in. foam for headband	N/A	N/A	N/A	N/A	Win-Shield	-	N/A	N/A
Double sided tape	2	1.5 in. x 60 yards 3M double sided adhesive	N/A	N/A	N/A	N/A	Win-Shield	-	3M	3M 300LSE
3D printer	1	For 3D printing hinge parts and molds	N/A	N/A	N/A	N/A	North Forge Fab. Lab	-	-	-
3D printer filament	2	1kg spool of PLA filament	25.99	-	51.98	-	Amazon	0810031292912	OVERTURE	OVA175
Generic face shield	1	Used to fill in the hole in the face shield	N/A	N/A	N/A	N/A	University of Manitoba	-	N/A	N/A

8.2 Project Specific Materials

8.2.1 Strength Test Results (see section 3.5)

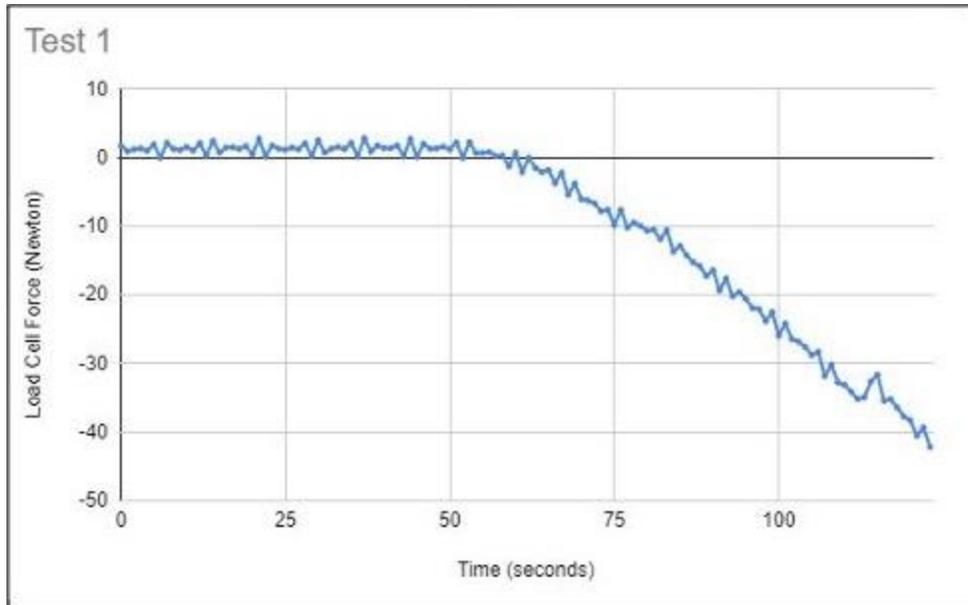


Figure 19: Results from Strength Test 1

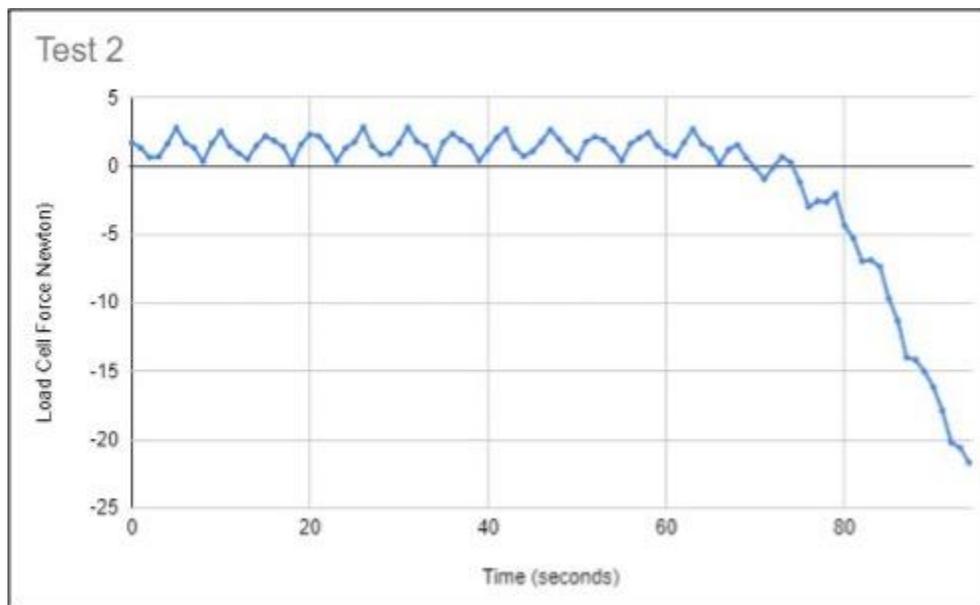


Figure 20: Results from Strength Test 2

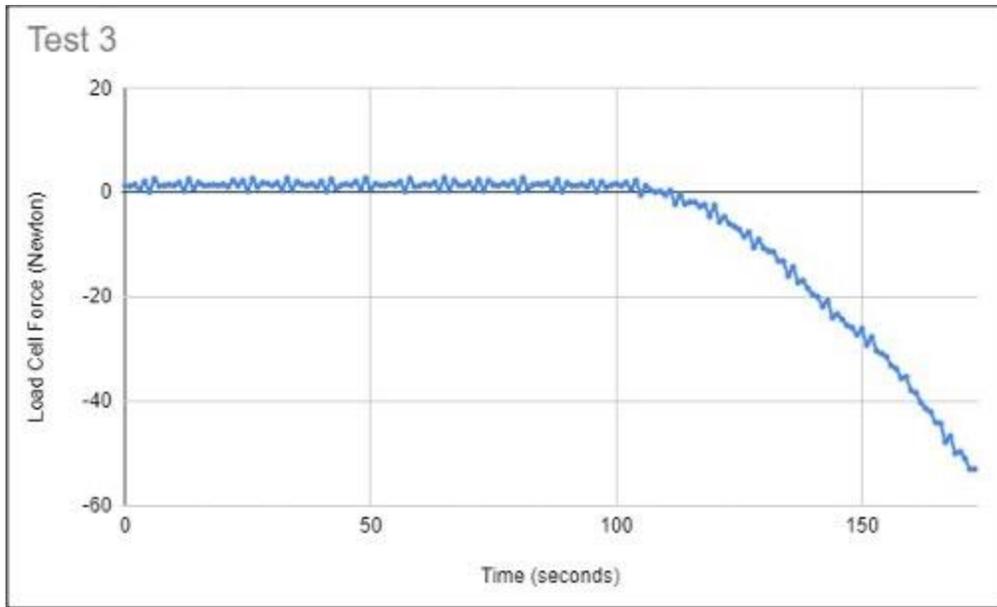


Figure 21: Results from Strength Test 3