KnE Life Sciences
SIRES
Science and Technology Research Symposium (SIRES)
Volume 2022

Conference Paper

The Development of Modular and Re-Usable Face Shields for COVID- 19 Prevention in Clinics

F. A. Yulianto*[1], A. A. Nurrahman[2], Y. S. Rejeki[2], N. R. As'ad[2], E. Amrullah[2], M. Nurhalim[2], M. A. Shakira[2] and M. M. Ibrahim[2]

[1]*Medical Faculty, Universitas Islam Bandung, Bandung, Indonesia*
[2]*Technical Faculty, Universitas Islam Bandung, Bandung, Indonesia*

ORCID ID
F. A. Yulianto : https://orcid.org/0000-0003-3682-5744
A. A. Nurrahman : https://orcid.org/0000-0002-4542-4734
Y. S. Rejeki : https://orcid.org/0000-0002-3612-6401
N. R. As'ad : https://orcid.org/0000-0002-8469-9124

Corresponding Author: F. A. Yulianto; email: awaliayulianto@gmail.com

Published 27 December 2022

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the SIRES Conference Committee.

Abstract.
COVID-19 continues to cause a high fatality rate - especially in health workers. Safety protocols in nearly all aspects of our lives were announced to minimize the spread of the disease. A common personal protection equipment (PPE) that is used as a safety precaution is the face shield, a portable barrier to protect human to human transmission. Unfortunately, this simple, mass-produced device has not been made in a standardized way. This study aimed to create a standard modular and ergonomic face shield that can be dispatched, recleaning, sterilized, and partially renewed. Polyethylene Terephthalate (PET) and Polylactide (PLA) filaments were selected as the materials to be used. PETs with 0.3 mm thickness were used for the visor. The headband was designed in AutoCAD 2019 then produced by a Flashforge 3D printer. Nurses' anthropometric measurement was used as guidance in formulating the size of the head band. 60 head bands were produced in 2 months of 5 working days (80 minutes for each headband). This device was given to non-government clinics that have short PPE supplies and was evaluated according to their reliability and comfort. We concluded that this new PPE had minimum visual distortion, was easy to dismount, and easy to replace, except for the headband.

Keywords: covid-19, face shield, prevention

1. INTRODUCTION

Per today the Covid-19 number is still accelerating, led by new cases and followed by the mortality rate. It increases exponentially in every part of the world. Every human being is vulnerable, despite in different scale of risks [1]. A study in Canada described health workers as a career that had the highest risk for being contracted by Covid-19. It was obvious due to the first destination for a sick person would be health centre [2]. A research conducted in Daegu South Korea concluded infection of Covid-19 in nurses were twice the incidence in doctors [3].

Health workers problems during this pandemic will make other problems such as the lack of human resources that needed more especially in this dire situation. International amnesty had released death over 3000 health labours due to Covid-19 [4]. Therefore, health worker's safety is an important issue for fighting this pandemic including in Indonesia. Indonesia as a big country had massive death toll on health workers, top 15 countries in the South East Asia. Thus, serious measures is needed to cope the problem [4].

The spread of Covid-19 in Daegu, South Korea, was halted successfully by a group of interventions. They were reorganization of regional health system, hospital intervention and specific intervention. Protective personal equipment (PPE) was included in specific intervention [3]. Unfortunately, there were PPE shortage across the nations due to high demand and low supply during the pandemic. Indonesia experienced the same thing that make government tried so hard to supress the price despite its resistance. Along with government, communities created fund raising as

well in order to help health centres but another problem came. Supply disparities appeared especially in private health centres, especially in remote areas.

One of the PPEs that always appeared was face shield. This device is supplemental to face mask and applied because of the hypothesis of Covid-19 spread by aerosol and make contact with the face. Today level 2 and 3 PPE using face shield as a standard device to minimize the risk of contracted Covid-19, although it generally used for everyone as well. Despite of its popularity, there are no standardized face shield so the size or the shape could be varying. Chances are everyone can make face shield and test it [5].

Health service has function as a working place for staffs beside as a destination to seek treatment for patients. 2020 patient safety focused on health worker safety because of pandemic status. It would be impossible if a sick person can visit the health centre safely when the staff become a source of infection. Biological hazard must be controlled from elimination to protection level, which is PPE application.

Universitas Islam Bandung (Unisba) as an accredited nationally and internationally has units that can create standardized face shield. The main idea came from medical faculty as unit that creating medical staff, playing big role in fighting the pandemic, whereas the industrial faculty could create the physical face shield. Main purpose of this study was to have standardized face shield to minimize risk of infection during usage and after usage. Modular design that allow knock down, cleaning, and sterilization for each parts will be playing big part to decrease the risk.

2. METHODS

2.1. Literature Review

Medline database were used to find safety materials that fit the requirements. The results showed Polyethylene terephthalate (PET) as a safe material ranging from food apparatus to cardiovascular stent [6]. The abandoned styrofoam era make PET as the common material that easy to access for laymen. The structure was similar to plastic with advantages over its transparency and heat resistant, therefore it was the perfect material to protect the face while uninterrupting activities.

The visor would be difficult to be attached directly to the head, thus a connector between the visor and the head was needed. From the previous sample we found headband as the connector hence we were looking for material for the headband that also safe due to it was the part that made direct contact with the skin. Other prequisite was the material also could be used in a 3d printer. Material for the headband was Polylactide (PLA) filament. This filament is an alternative to petroleum-derived products such as common plastics, with hypoallergenic and washable property. It is derived from renewable resources as a non-aromatic polyester [7]. This material was also used as a composite mesh for ventral hernia repair, so it was safe to use them [8].

2.2. Headband

Face shield are divided in three components: headband, visor, and fastener. Nurses of Indonesia are the source population for the size of head band and visor. Age are ranging from 25 – 40 years old. Head's width and length were used. 95^{th} percentile of head's width and length were chosen, thus usage are permitted even for them who have extreme size (Table 1).

TABLE 1: Size dimension.

Dimension	Anthropometry		Percentile		SD
		5th	50th	95th	
D26	Head's Width	17,25	17,96	18,67	0,43
D27	Head's Length	16,2	19,25	22,31	1,86

AutoCAD 2019 was used as an application with predetermined size from the Indonesian nurse's anthropometry measurement. 2- and 3-dimension visualization in Figure 1 and 2 below. The face shield design then printed in Flashforge 3D Printer as a prototype with picture as in Figure 3.

The headband is a part that directly make contact with human body, therefore it should be safe especially for skin. The PLA may cause irritation (mild irritation) to skin due to mechanical action and reaction with water (sweat), not chemical reaction. Thus, fixated and light weight headband is mandatory to prevent mechanical action. The PLA is

stable substance with slow reaction in the presence of water. This material is not met to be burnt because of carbon monoxide and / or carbon dioxide may arise from combustion of this product [7].

Figure 1: 3-dimension visualization.

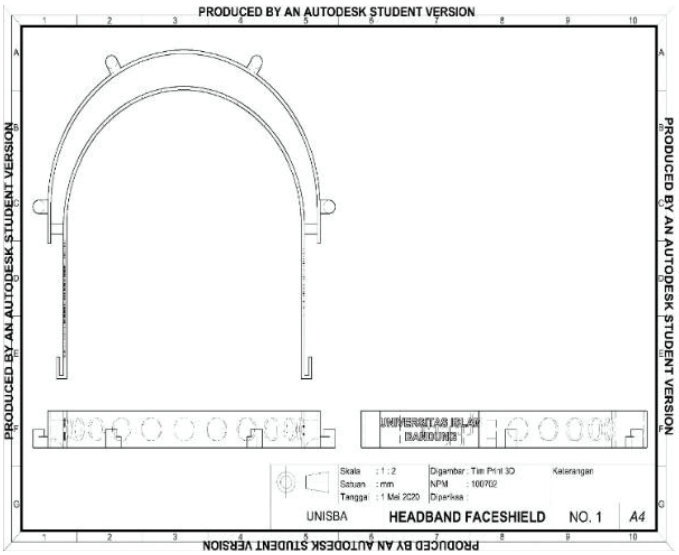

Figure 2: 3-dimension visualization.

Material for the visor was transparent Polyethylene terephthalate (PET) with 0.3 mm thick. It is resistant against microorganisms, lightweight, easy to transport, and shatterproof as well. Another property such as completely recyclable has another advantage. It is commonly used as a food grade material, thus easy to have [9].

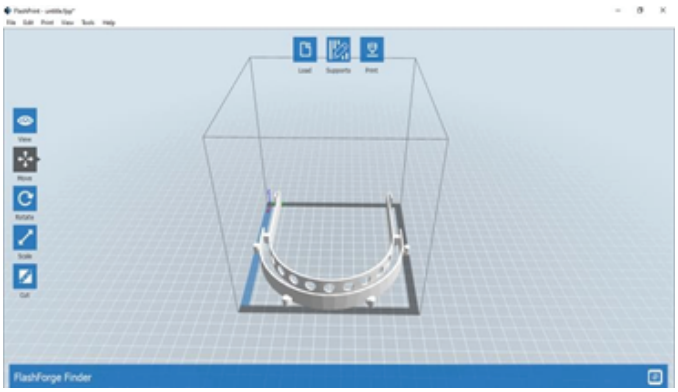

Figure 3: Pre-printing visualization.

Length of face in anthropometry was used as length of the visor, while the width was used for the visor's width. It was a simple acrylic that easily found as a cover for paper in printing services nearby. The thickness would be very important because it is a lot thicker than ordinary transparent cover. 4 holes were made by simple paper perforator, with distance between them were decided by the distance between puncher in the perforator. To minimize the cost, the transparent PET was bought in a roll, cheaper and could be mass produced.

The decision to choose this material was made to have an easy replacement whenever it needed to be replaced. In addition, the stiffness would be an added value to minimize the probability for swinging and spreading the aerosol. There were complains about other face shield that produce visual disturbances, distortion that creates vertigo when used in a prolonged time. Therefore, the visual disturbance was also a criteria to be minimized.

2.3. Fastener

Fastener selection was chosen the same way as the visor selection. It should be easy to replace, easy to wash, and easy to disinfect. Velcro was chosen because it was cheap, in addition to the previous criteria. Two modular parts above, visor and fastener, were easy to have, therefore reusable and friendlier for the environment.

Fastener is a part that make contact with the body as well as the headband. The safety for skin contact must be considered. Velcro is a non-toxic and non-allergenic patent, that unlikely to cause skin irritation. However, melting process will release vapours that may cause eye, skin, and respiratory tract irritation. Conclusion, this material is safe to use [10].

3. RESULTS

The budget for single face shield was Rp. 10.000,- ($0.70). Time production was spent the most for creating the headband. Single printer only produce single headband in 80 minutes, resulted in nearly 2 months of office hours production. Visor and fastener productions were the quickest, approximately 10 minutes only to create them.

60 headbands were created from single roll of PLA filament (Figure 4 and 5). There were three headbands that broken when docked with the visor due to fragility of the material. The visor and fastener part was made manually. Some of products were used in Unisba clinic to be evaluated directly by users. Over all, the face shield has low weight, comfort around the head, and no visual distortion. No fog reported during usage in the campus clinic.

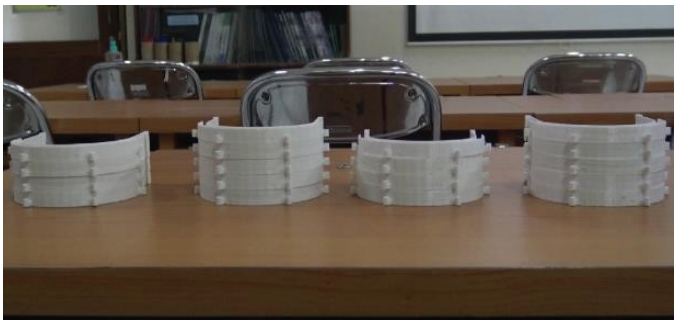

Figure 4: Headbands.

Figure 5: Face shields.

4. DISCUSSION

Time that needed in production of a face shield was large. Single 3D printer can only create one headband in 80 minutes, therefore our team was planning to create customized 3D printer with large platform that can simultaneously create 3 or 4 headbands

in single process. However, that idea was not the only one. Creating several casts will be much more cost efficient, although other problem such as inability to use PLA filament in a block cast. It is true that nowadays there are some ways to make a bioplastic, a safe material similar to PLA, but the time consumption is still large. Combining starch, glycerol, vinegar and aquabidest requires boiling in a few minutes but need a lot more time for cooling them down for at least two days. Injecting silicon into a cast is feasible, despite the attention on more amount of cost that will be needed.

The headband part was the most important part that connect face shield with the user, it was associated with elasticity of the headband to create a comfortable application of face shield. Chosen size was fitted adequately in 14 staffs of Unisba clinic, with no headache experience for 4 hours usage. Its comfort was a trade off from its tensile strength, proved in couple of headbands that broken when connected to the visor. Further specific measurement between tensile strength and degree of comfort must be conducted to have correct material strength.

However, there was a visual problem where smooth scratches were found thorough the visor. Despite there was no visual distortion, the scratches made the view unclear. 0.3 mm PET is a safe material that common. We can have it by browsing the online market and have it at our home. However, there were several issues regarding the quality of the surfaces. By specification, the PET is scratch resistance but we found it was wrong. The visor part was sensitive. Thus scratches were easy to make. We still confirm to the vendor about how far the quality of the PET visor.

This visor actually quite tensile that make the perforator sometimes will not be perforating the PET easily. Second try should be enough to make couple of holes in the visor. Another try with ordinary transparent film that commonly used as papers cover might be worth to try despite their soft and fix size properties.

All parts of the face shield was cleaned by soap and disinfectant, continued by sterilized in ozone sterilizer to see the reusability. There were no damage on every part of it. The reliability of this device is recommended although there was a minor problem with visuals.

5. CONCLUSION

A PPE that made with proper measurement and materials is created to help the health workers against the pandemic. Do not forget that this is a supplemental device to face masks in PPE hierarchy of control. Elimination, substitution, engineering, and administrative control must be conducted first before PPE implementation. This PPE

is recommended to use in health workers, and people as well, due to its properties such as modular, easy to change (except the headband part), easy to clean, and able to sterilize. Usage of the face shield only is not recommended.

ACKNOWLEDGMENTS

This product was sponsored by Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Unisba, The Research and Community Service Unit of Unisba.

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