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Research article

Establishing local manufacture of PPE for healthcare workers in the time of a global pandemic

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ABSTRACT

A face shield is a secondary personal protective equipment (PPE) for healthcare workers (HCW). Worn with the appropriate face masks/respirators, it provides short term barrier protection against potentially infectious droplet particles. Coronavirus disease 2019 (COVID-19) caused a spike in demand for PPE, leading to a shortage and risking the safety of HCW. Transport restrictions further challenged the existing PPE supply chain which has been reliant on overseas-based manufacturers. Despite the urgency in demand, PPE must be properly tested for functionality and quality. We describe the establishment of local face shields manufacture in Western Australia to ensure adequate PPE for HCW. Ten thousand face shields for general use (standard) and for ear, nose and throat (ENT) specialist use were produced. Materials and design considerations are described, and the face shields were vigorously tested to the relevant Standards to ensure their effectiveness as a protective barrier, including splash and impact resistance. Comparative testing with traditional and other novel face shields was also undertaken. Therapeutic Goods Administration (TGA) licence was obtained to manufacture and supply the face

Abbreviations: AS/NZS, Australian/New Zealand Standard; COVID-19, coronavirus disease 2019; ENT, ear, nose and throat; HCW, healthcare workers; ISO, International Organization for Standardization; PETG, polyethylene terephthalate glycol; PPE, personal protective equipment; TGA, Therapeutic Goods Administration.

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shields as a Class I medical device. The swiftness of process is a credit to collaboration from industry, academia and healthcare.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic caused a sudden increase in demand for personal protective equipment (PPE) leading to shortage through the regular supply chain. Healthcare workers (HCW) providing routine care to patients are exposed to an occupational hazard in the form of sprays and splashes of body fluids containing infectious microorganisms. Droplets of these fluids may be inhaled or deposited on mucous membranes in the eyes, nose and mouth, potentially infecting the worker [1]. Face shields in the healthcare setting are designed to provide protection of the facial area against these droplet particles. It is noted that the SARS-CoV-2 virus causing COVID-19 is highly contagious and easily transmitted by respiratory secretions (droplet or aerosol) and also indirectly via contact [2]. Masks and particulate filter respirators capable of filtering out viral particles, i.e. N95/P2 masks, have been recommended in aerosol generating procedures [3]. Worn in conjunction with appropriate masks or respirators, face shields can provide adjunct respiratory protection for HCW caring for infected patients.

At present, there is no universal standard for face or eye protection from biological hazards and the recommendations for design and efficacy vary between regulatory bodies. A face shield provides barrier protection and generally consists of a visor, a frame and a suspension system that can be manufactured from a choice of different materials [4]. In terms of infection control, face shield design depends on the route of exposure, other PPE used concurrently and personal vision needs. In our case, there was an urgency to produce face shields within a short time frame to ensure sufficient local supply for HCW during the COVID-19 pandemic [5]. When supply of crucial elements of care become difficult to acquire, this endangers not only the welfare of HCW but also the ability to provide appropriate care to patients [6,7]. The major aim was to quickly design and manufacture face shields in large quantities to satisfy local demand while still producing a product which was compliant with the relevant standards. The main considerations during the design process and material selections include coverage; fit and audio visual clarity for wearer; the ability to manufacture at scale using available raw materials; and cost of manufacture. Standard issue face shields supplied to Royal Perth Hospital (RPH) were used as a reference and our design was chosen for its simplicity to manufacture and availability of the materials that make up its components: a clear plastic visor, a forehead cushion and an elastic head strap.

Two types of face shields were proposed: one for general use (standard) and one for ear, nose and throat (ENT) specialist use. ENT face shields need to accommodate the wearing of a head-worn headlight or optical scope with sufficient side coverage. The ENT modified face shield is an innovative product as, prior to the COVID-19 pandemic, no similar product was commercially available. We previously described in brief the design and manufacture of ENT modified face shields to fit the Vorotek O scope used by most Australian otolaryngologists [8]. The current paper describes in greater detail the design process, testing and manufacture of both standard and ENT face shields. A series of testing was performed to select the most suitable materials for the face shield components. Design prototypes were manufactured using the chosen materials and then evaluated for their fit and functionality as a protective barrier.

Following this iterative design and testing process, final designs were established for the standard and ENT face shields. Therapeutic Goods Administration (TGA) certification was sought and granted for the manufacture of the face shields as a Class I medical device (ARTG Identifier 335202). The entire process took 60 days from when the idea was conceived to 10,000 face shields being produced [9].

The coronavirus disease 2019 (COVID-19) pandemic resulted in similar efforts to establish local manufacturing for face shields with mixed success [10] and the development of new methods to assess the protection offered by face shields, goggles, and safety glasses [11].

2. Materials and methods

2.1. Face shield design

The standard and the ENT face shields share the same device components and assembly procedure, differing mainly in the dimensions of the components used. Each face shield consists of three main components: a visor made of polyethylene terephthalate glycol (PETG), a forehead cushion made of foam and an elastic head strap (Fig. 1). As previously described [8], PETG sheet (500 μm,

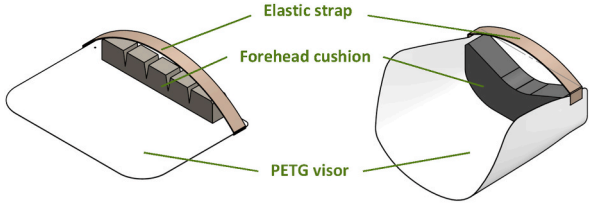

Fig. 1. Face shield components. Standard face shield (left) and ENT face shield (right) are depicted.

Adarsh Australia) was laser-cut to design specifications to form the visor. Polyether-urethane foam (Dunlop Foams C.A.S. Number: 9009-54-5) was attached to the visor using a food-grade cyanoacrylate glue (Loctite 435, Henkel). A custom-made jig was used to ensure reproducibility in applying the glue. Elastic head straps (Adarsh Australia) were attached to the visor by retention buttons which were applied using a button press through laser cut holes on the PETG sheet.

The design for the standard face shields was reviewed and approved by the coordinator of Infection Control and the director of the COVID Clinic at RPH. The design for the ENT face shields was reviewed and test-fitted by a consultant ENT surgeon and several ENT registrars.

The ENT face shield required added clearance behind the visor compared to the standard face shield in order to allow the wearing of the Vorotek O scope. With the binocular optic of the scope positioned up, the distance anterior to the forehead was measured (40 mm) and used as a guide to design the forehead foam cushion [8]. Increased distance between visor and the wearer meant greater coverage is needed for droplet protection, therefore a winged design and higher curvature of the visor was adapted for ENT face shields in order to provide extra side protection for the wearer.

The design and production steps relating to the face shields manufacture were subjected to rigorous design and process failure mode and effects analysis (DFMEA and PFMEA) to identify and minimise risks according to IEC 60812 [12]. Representatives from healthcare, personnel with medical device experience and the contract manufacturer all had input into the DFMEA and PFMEA. Compliance to the TGA Essential Principles for medical devices was demonstrated for both the standard and the ENT face shields and a design dossier compiled. Detailed work instructions for the manufacturing steps were prepared and a quality assurance schedule devised. Additionally, COVID-Safe measures to monitor the health of the staff manufacturing the face shields were prepared and followed throughout the process.

2.2. Material selection

2.2.1. Strap testing

Seven elastic strap materials were assessed. The straps were cut to a 250 mm length and evaluated for their elasticity using an Instron 5566 mechanical tester. Each strap was stretched to 1.5 times its length at a rate of 200 mm/min. A strap removed from a standard issue face shield supplied to RPH was used as a reference. The amount of force required to stretch each material was recorded and compared (Fig. 2).

2.2.2. Retention button size and configuration

Two sizes of retention buttons were examined. Test specimens of the buttons fixed to a length of strap material and a piece of visor material were prepared. An Instron 5566 was used to pull the test specimens, in shear or in peeling configuration (Fig. 2 (inset)), at 200 mm/min until failure.

2.3. Functional tests

Following the material selection process, design prototypes for both the standard and ENT face shields were manufactured at

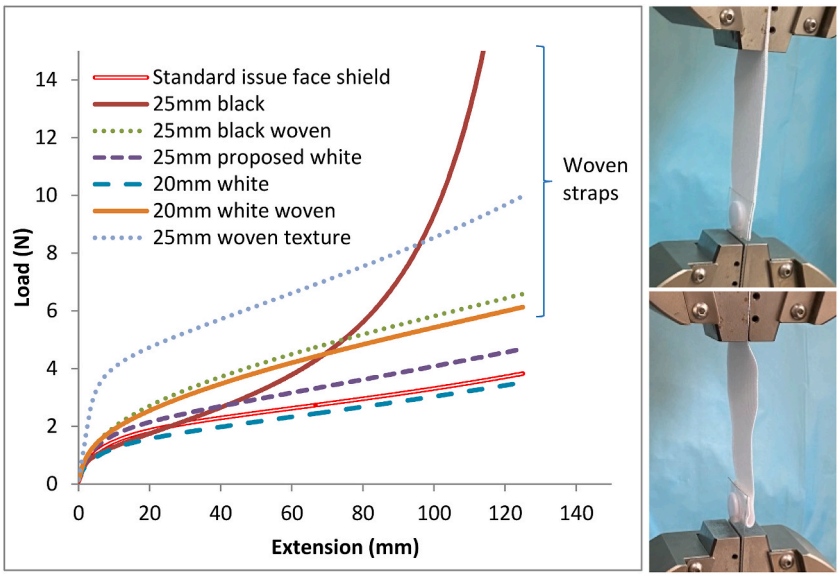

Fig. 2. Elastic properties of candidate strap materials. The amount of load applied against the resulting extension for each strap material is shown. Inset: Test setup of retention buttons in shear (top) and in peeling (bottom) configurations on an Instron 5566 mechanical tester.

Adarsh Australia. The prototypes were tested for fit for a range of head sizes and durability during normal wear. In terms of barrier protection, they were evaluated for their splash resistance, low impact resistance and resistance to penetration using testing parameters in accordance to Australian/New Zealand Standard (AS/NZS) 1337.1:2010 [13]. The performance of the prototypes was compared to those of a standard mask visor (Halyard) and a 3D printed variant, which design was available from the web and uses a transparency sheet as the visor [14].

2.3.1. Test-fitting on ISO headforms

Prototypes of the standard and the ENT face shields were test-fitted on three 3D-printed headforms (Fig. 3) representing the small, medium and large head size categories of the population [15]. These International Organization for Standardization (ISO) Digital Headforms were specified in ISO 16976–2 [16] and were 3D-printed on a ProJet CJP 660Pro (3D Systems, Rock Hill, South Carolina, USA). The strap-length was adjusted so that the fit was acceptable on each ISO Digital Headforms, ensuring that a single strap-length would be acceptable to wearers with different head-shapes.

2.3.2. Splash resistance

Splash resistance is a measure of a product's resistance to droplets or liquid splashes. The splash resistance test was performed per testing guideline from AS/NZS 1337.1:2010 Appendix V [13]. Each test face shield was mounted on a headform (CPR manikin in this instance) of which the ocular area was covered with a white blotting paper (180 mm × 100 mm) that had been dipped in 0.1 M sodium carbonate and dried [8]. The test face shield was sprayed with a phenolphthalein indicator solution using a fine droplet atomiser at a distance of 600 mm from the headform. The blotting paper was then examined for colouration which is indicative of reagent penetrating the face shield barrier. Control spray test was performed on a headform that was not protected by a face shield. According to the standard, a single spray is required for a valid test.

2.3.3. Low impact resistance

Low impact resistance is a measure of a product's resistance to impacts from objects travelling at low velocities. The low impact resistance test was performed following testing guidelines from AS/NZS 1337.1:2010 Appendix K [13]. A CPR manikin wearing the test face shield was placed in the supine position. A spherical steel ball (approx. 22 mm diameter, 42 g weight) was dropped onto the shield from a height of 1.8 m, guided by a metal tube. The test face shield was examined for the following: cracking through the visor thickness, detachment of more than 5 mg of material from the surface, whether the ball passed through the visor, dislodgement of the visor and contact between the shield and the eye area. According to the standard, 3 tests were performed per product: either side of the midline and above the ocular, within 20 mm of the mid-line.

2.3.4. Resistance to penetration

Resistance to penetration is a measure of a product's ability to withstand penetration from small, sharp objects projected towards it. The resistance to penetration test followed testing guideline from AS/NZS 1337.1:2010 Appendix P [13]. The test was set up similarly to the low impact resistance test above, but a Singer sewing machine needle (equivalent to 3355–01/25/200) was used as the projectile

Fig. 3. 3D printed ISO headforms mounted with face shields. The small (left, with an ENT face shield), medium (middle) and large (right, with a standard face shield) headforms are representative of the head size groups of the population, and were used to gauge the length of face shield strap required to accommodate the range in head sizes.

instead of a steel ball. The test face shield was then examined for cracking of the visor, piercing through the visor and contact between the shield and the eye area. According to the standard, 2 tests were performed per product, either side of the midline.

3. Results

PETG has been used in the manufacture of commercially available face shields and tends to be more economical than other similar materials [4,17]. The 500 μm PETG stock was chosen due to its good clarity and light transmission.

After the iterative design process, the standard face shield produced was 325 mm wide, 235 mm high and weighed 75 g. The ENT face shield was 458 mm wide (less when contoured around the face), 235 mm high and weighed 105 g.

Of all the strap materials tested, two had similar elasticity profiles to that of the standard issue strap. Fig. 2 illustrates the amount of force needed to stretch the strap materials to achieve a certain amount extension. The 20 mm white strap had the closest profile to the standard issue strap and had a good stretch while the 25 mm white strap required slightly higher force to achieve the same amount of extension (i.e. slightly less stretch). It was thought that the 25 mm strap might be more comfortable than the 20 mm strap as the wider strap may alleviate pressure point for the wearer by distributing it over a larger area. Woven strap materials were found to have lower stretch properties that may cause discomfort and limit the head sizes that can be accommodated and therefore were not recommended. Based on these results, the 25 mm white strap was proposed to be the strap material for the face shields.

Comfort is an important consideration when selecting the optimal strap material as Face Shields can be worn for extended time periods. In lieu if assessing the comfort of the strap on a range of people, prototype face shields were test-fitted on 3D-printed headforms (Fig. 3) representing the small, medium and large head size categories of the population. The strap-length was adjusted so that the fit was acceptable on each of the ISO Digital Headforms to maximise the comfort for the wearer of the Face Shield.

The retention button configuration (Fig. 2 (inset)) was found to have a substantial effect on the failure load, with buttons in shear requiring a much higher force to break than those in peeling configuration, irrespective of size. Small buttons in shear and in peeling configurations failed at a load of 218 N and 95 N, respectively. Similarly, large buttons in shear had a higher force to failure (201 N) than those in peeling configuration (49 N). To reach such a high load would require a substantial extension of the strap far beyond normal donning and doffing of the face shield, therefore either configuration was found to be acceptable. The buttons in shear had a higher failure load and thus a greater margin for safety. A decision was made to use the small buttons (12.4 mm diameter) in shear configuration for both the standard and the ENT face shields.

Results for the splash resistance test are summarised in Fig. 4. The standard face shield passed the splash test as indicated by the absence of colouration on the blotting papers in the test area (Fig. 4 (b)). The control sample validated the working of the method. Initial design of the ENT face shield includes a cut-out profile of the forehead cushion to accommodate wider circumferential coverage. Fig. 4 (c, right) showed some penetration of the indicator solution at the top of the blotting paper, likely through the cut-outs on the foam. The foam for the standard face shield was also designed with cut-out profile to accommodate head curvature (Fig. 1, left)

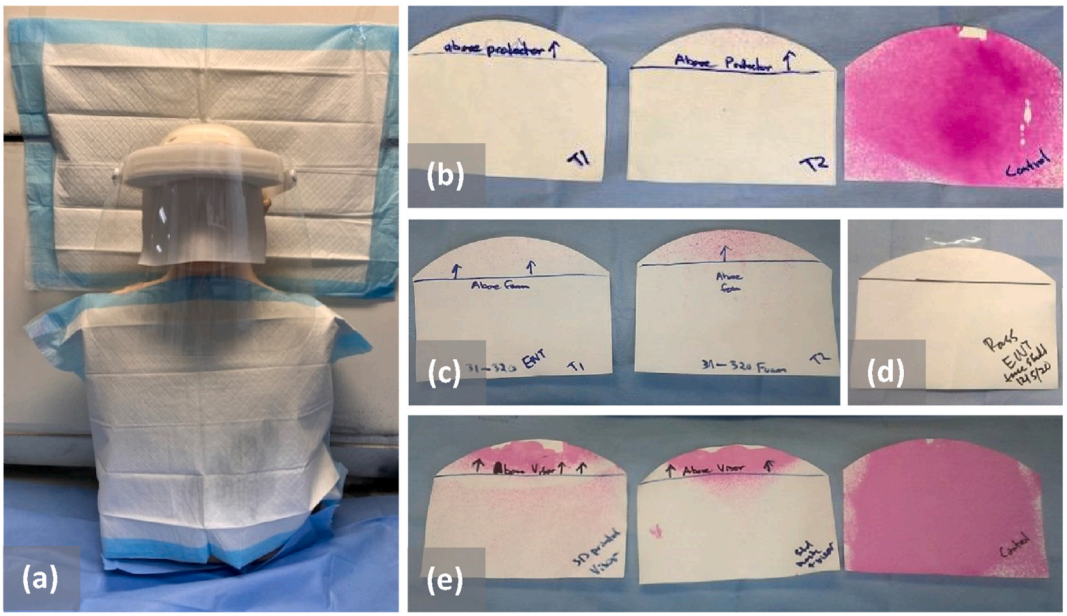

Fig. 4. Test setup for splash resistance evaluation. A test face shield is mounted on a headform with a white blotting paper covering the ocular area (a). After spraying with an indicator solution using a fine droplet atomiser, the blotting paper was removed and examined for colouration which indicates droplets penetrating the face shield barrier. The horizontal line on the blotting paper delineates the forehead cushion. Results for the standard face shield (b), initial ENT face shield (c), revised ENT face shield (d) and the 3D printed face shield and standard issue mask visor (e), are shown. Control was performed by spraying the headform that was not protected by a face shield.

however these close fully to form a seal that prevents droplet penetration. The profile of the ENT foam was then changed to a smooth curve (Fig. 1, right) and the resulting ENT face shield passed the splash test (Fig. 4 (d)). It was evident that the 3D printed face shield that used an A4 transparency as a visor did not pass the splash test (Fig. 4 (e, left)). It can also be seen that some droplets penetrated the standard issue mask visor (Fig. 4 (e, middle)), however it is important to note that the visor mask combination was only tested for comparative purpose only and is not indicated to be splash resistant in the current setup.

The standard and ENT face shields passed all the observation criteria in the low impact resistance test (Table 1). No cracking was observed on the visor of both shields after impact and the steel ball did not pass through the visor. The visor was not dislodged from its normal position and no contact occurred between eye and the shield. The transparency visor on the 3D printed face shield did not crack upon impact. Even though the steel ball did not pass through the transparency visor, it caused the visor to be dislodged and make contact with the eye area. The thin and flexible visor of the standard mask visor was bent inwards and touched the eye area upon impact; however, the mask visor passed the rest of the testing criteria.

Fig. 5 illustrates the test setup for the resistance to penetration test with close up images showing the marks left on the visors following contact with the needle. The PETG visor on the standard and ENT face shields remained intact with only dents present after being struck by the projectile needle (Fig. 5(b)). The PETG visor was also rigid enough to prevent it being bent inwards towards the ocular area. The thinner visors on the visor mask and on the 3D printed face shield however were pierced by the needle during testing (Fig. 5(c) and (e), respectively) and made contact with the eye area as the projectile needle landed on the test objects (Fig. 5(d)). The test criteria and results from the resistance to penetration evaluation are summarised in Table 2.

4. Discussion

COVID-19 infection presents at disproportionately high levels among HCW. Current government guidelines in Australia advise contact and droplet precautions in the routine care of suspected or confirmed cases of COVID-19, and contact and airborne precautions during aerosol generating procedures [18]. There have been multiple review and perspective articles written to better understand the route of infection and best practice of PPE wear for HCW handling COVID-19 cases. Reports on actual tests performed on the effectiveness of standard issue PPE are more limited and there have been no reports that emphasised the importance of the superior barrier in droplet precautions, which our tests have demonstrated.

In addition to inhalation or ingestion, viral transmission via eye contamination is very low but it exists. One of the expert taskforce who visited Wuhan developed COVID-19 despite fully gowned with protective suit and the N95 respirator, with his first symptom being unilateral conjunctivitis [19]. Overall risk of contamination from blood and body fluid splash on protective eye shields during surgery has been reported to range from 22.3 to 76.9% [20–27]. HCW often do not detect contaminations, up to 92%–100% of the time [24,26–28], which emphasises the importance of having appropriate PPE and being well versed in the correct donning and doffing procedure. Depending on the type of surgery, masks with visors may not provide adequate protection [29].

Traditionally, surgeons have not worn eye protection for reasons including visual disruption; discomfort, fogging, reflection and refraction of light; the lack of availability of eye/face protection; spectacles not fitting under protection; or the feeling that their own spectacles provide adequate protection [21,22,30–32]. Chong et al. has shown through a mathematical model that prescription glasses alone could prevent splashes: 100% laterally, 92.6% medially, 77.8% inferiorly and 0% superiorly [31]. Lateral contamination has been reported to occur in 5% of procedures [23]. Wearing a well-fitting face shield with superior protection may address some of these concerns. Shoham et al. found that a surgical mask with visor, as well as safety eyeglasses with a N95 respirator, resulted in eye contamination with oil-based fluorescent dye, whereas a full face shield did not [33].

A face shield provides greater protection to the wearer against body fluid splatters and alters the particle size distribution and magnitude of inhaled aerosols when compared to a standard face mask with visor or goggles [34]. A recent comprehensive review of face shields for infection control by Roberge cited recommendations from the USA Centers for Disease Control and Prevention for visors to have sufficient width to reach at least the point of the ear to reduce the chance of a splash going around the edge and resulting in eye and face contamination [4]. Crown and chin protection is also recommended for improved infection control. It is also crucial to understand the importance of comfort and fit through the suspension system, as face shields are likely to be worn for an extended period and need to accommodate a range of head movements. More than half the respondents to a survey of surgeons from 26 countries felt that additional PPE during the COVID-19 pandemic hampered their surgical performance due to hindrance to visibility and communication, decreased comfort and increased fatigue [35]. Face shields should also be worn centred for balance and the suspension should sit between 0.5 and 1 inch above the eyebrows [17].

In our design, PETG was selected as the visor material due to its excellent clarity and light transmission and relatively low cost. The

Table 1
Summary of observations from the low impact resistance test.

Face Shield	Visor cracked through its entire thickness	Ball passed through the visor	Visor dislodged from its normal position	Contact between eye and protector
Standard face shield	No	No	No	No
ENT face shield	No	No	No	No
Standard mask visor (Halyard)	No	No	No	Yes
3D printed with transparency sheet	No	No	Yes	Yes

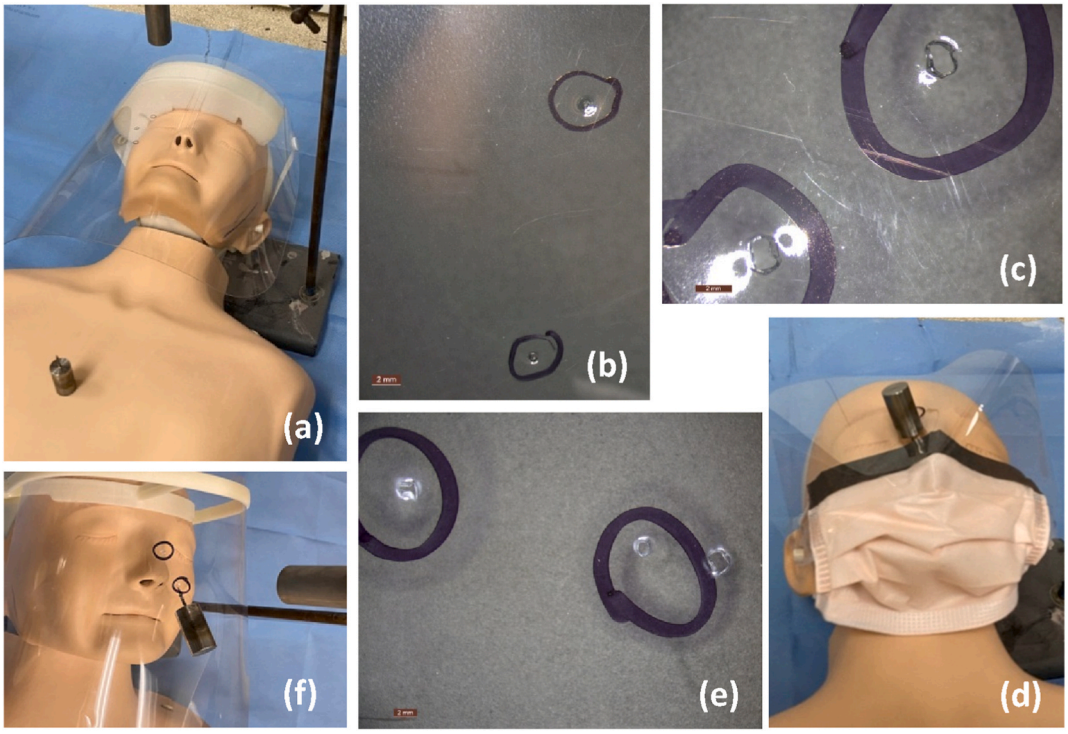

Fig. 5. Test setup for resistance to penetration evaluation. The test face shield is mounted on a headform facing up, with a projectile sewing needle dropped on the shield through a metal tube (a). Dents were observed on the PETG visor of a standard face shield after being struck by the needle (b). The needle penetrated the visor of a standard issue visor mask (c) and caused it to bend inwards contacting the eye area (d). Holes were also visible on the transparency visor (e) of the 3D printed face shield following the test (f).

Table 2
Summary of observations from the resistance to penetration test.

Face Shield	Visor cracked	Point pierced visor	Contact between eye and protector
Standard face shield	No	No	No
ENT face shield	No	No	No
Standard mask visor (Halyard)	No	Yes	Yes
3D printed with transparency sheet	No	Yes	Yes

polyether-urethane foam frame was selected for its sturdiness while also providing a comfortable seal against the forehead and barrier against droplet contamination superiorly. The wider 25 mm strap material was chosen as it may be comfortable to wear than the thinner bands, with elasticity that can accommodate a range of head sizes. The design comprising superior barrier along with adequate length and width has been shown to offer protection to fine droplet particles as well as from low impact and penetration by sharp objects.

The need for an ENT modified face shield was identified as standard issue face shields are not able to accommodate the wearing of a headlight [8]. The Vorotek headlight is widely used by otolaryngologist surgeons and trainees in Australia. Protection during clinical setting is important as the glasses do not provide adequate protection against splash or droplets contamination to the conjunctival mucosa. In addition, due to the design, cleaning and sterilisation may pose a problem.

The ENT face shield passed the low impact and penetration tests but initially failed the splash test as the indicator solution passed though gaps in the forehead foam cushion. A redesign of the ENT foam profile solved this problem and the updated ENT face shield subsequently passed the splash test to provide droplet protection superiorly. This demonstrates the importance of product testing and iterative design when producing PPE, even when under significant time-pressure to supply these devices.

It is important to note that the standard issue mask visor was not designed to offer aerosol protection, however its reported use when no other PPE was available prompted this comparative testing. The visor mask is indicated by the manufacturer for surgical use with fluid resistance at 160 mmHg (synthetic blood) that meets the ASTM F1200-11 standard for fluid-resistant protection [36], however is not indicated for procedures where aerosol is likely to be generated. We also noted that it was the urgent need of PPE that resulted in the 3D printed face shield with A4 transparency as visor to be designed and shared in goodwill; however its use as a proper barrier protection in clinical setting cannot be recommended due to its failure in the functional tests.

Despite their performance as the first line of protection to fine droplets as shown from our tests, the face shields must be seen as

secondary PPE that complements the primary protection from the recommended type of surgical mask. Given that the COVID-19 is transmitted primarily by respiratory droplets in routine care, fluid resistant surgical mask is recommended during close contact, while a particulate filter respirators is recommended in clinical settings at higher risk of aerosols [37]. Evidence also suggests that infections cannot be neatly separated into airborne vs. droplet transmissions, which brings into question whether airborne precautions should be adapted at all times by HCW treating patients with suspected COVID-19 [38]. A simulation study by Lindsley et al. showed that wearing a face shield and increasing the distance from the coughing source significantly reduced the amount of cough aerosol inhaled [1]. This protection was most effective in the period immediately after a cough; in the first 5 min the amount of virus found on the respirator was 96% lower when a face shield was worn, however after 30 min this was reduced by 81%, likely because smaller particles were able to flow around it and accumulate over time. It was also less effective against smaller-particle cough aerosol with only 68% reduction of virus deposition [1]. Suboptimal adherence to wearing a face shield during aerosol generating procedure has also been shown to be associated (odds ratio 3.56) with acquiring an influenza-like illness while working on a ward with influenza A and B patients during peak influenza season [39]. This was significant even after adjusting for possible household contacts.

Australia was fortunate at the beginning of the pandemic for not experiencing a big surge in cases that overwhelmed our health system. While there was still supply issue, we had the time to test the PPE manufactured to ensure it is safe, effective and meets the required standard. While many industries have stepped in to address the supply chain issues with PPE, including manufacturing PPE by Additive Manufacturing (3D printing) [40], it is still important that any devices produced are verified to be safe and effective prior to deployment in the field to protect HCW and minimise the spread of infection. The current face shield manufacturing process is simple, relatively inexpensive (AUD 8.80/shield) and scalable with an established local supply chain [8]. Test subjects reported minimal complaints of fogging, heat accumulation around the facial area and of feeling claustrophobic. A TGA licence was granted to the Department of Medical Engineering and Physics, RPH, for the manufacture of the face shields as a Class I medical device.

5. Limitation

Our test did not examine the heterogeneity of the viral load between patients and the quantity of aerosol particles generated. Droplet size has been shown to be dynamic and changes during its transit from the respiratory tract to the environment with evaporation, with a large droplet able to become an airborne particle in less than a second [38]. This can be influenced by the type of aerosol generating procedure, temperature, relative humidity, ventilation and air exchanges in the environment. This aspect was not addressed in our controlled study.

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Author contribution statement

David Anthony Morrison: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Anastasia Nilasaroya: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper. Alan Matthew Kop: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data. Ryan Christopher Collier; Brendan Kennedy; Lachlan James Kelsey: Conceived and designed the experiments; Performed the experiments. Faz Pollard: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data. Jennifer Fong Ha: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of competing interest

Faz Pollard is the owner of Adarsh Australia, the contract manufacturer appointed to produce the face shields described in this article. Adarsh Australia received payment from the WA Department of Health to contract-manufacture these face shields. All other authors declare no competing interests.

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