

3D printed mask extenders: supplement to isolation masks to relieve posterior auricular discomfort

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Technical Note

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Abstract

Purpose

Many commonly used mask designs are secured by elastic straps looping around the posterior auricular region. This constant pressure and friction against the skin may contribute to increased wearer pain, irritation, and discomfort. The purpose of this work is to report a modified 3D printed mask extender to alleviate discomfort and increase mask wearability by relieving posterior auricular pressure from isolation masks.

Methods

Our institutional review board designated this project as non-human research and exempt. As part of resourcing 3D printing laboratories along with individual 3D printers to provide resources to healthcare workers, mask extenders were printed to relieve posterior auricular pressure from individuals wearing isolation masks. The authors modified an existing mask extender, increasing its length with accompanying peripheral rungs for isolation mask securement. 3D printing was performed with Ultimaker S5 (Ultimaker B.V.; Geldermalsen, Netherlands) and CR-10 (Creality3D; Shenzhen, China) 3D printers using polylactic acid filaments. The author's modified extended mask extenders were printed and freely delivered to healthcare workers (physicians, nurses, technologists, and other personnel) at the authors' institution.

Results

The final mask extender design was printed with the two 3D printers with a maximum 7 straps printed simultaneously on each 3D printer. Mean print times ranges from 105 minutes for the Ultimaker S5 printer and 150 minutes for the CR-10. 475 mask extenders were delivered to healthcare workers at the authors' institution, with the demand far exceeding the available supply.

Conclusion

We offer a modification of a 3D printed mask extender design that decreases discomfort and increases the wearability of isolation mask designs with ear loops thought to relieve posterior auricular skin pressure and ability to control strap tension. The design is simple, produced with inexpensive material (polylactic acid), and have been well-received by healthcare providers at our institution

Introduction

The COVID-19 pandemic has upended many facets of healthcare provision across the world. The need to protect frontline physicians, nurses, technicians, and other staff from infection has produced one of the

most visible changes: healthcare workers wearing masks, including respirators and isolation masks, for prolonged periods of time. In the setting of a pandemic, adherence to guidelines and infection prevention protocols is of particular importance, and the practical realities of following those instructions must be carefully considered to maximize compliance (1).

A 2012 study showed that mask discomfort due to heat, pressure, and pain significantly increases with increased duration of wear, and that discomfort may influence compliance with protocols for personal protective equipment (2). A survey of healthcare workers in China during the COVID-19 pandemic showed that 22% (90/404) of participants reported discomfort specifically due to the mask straps, more than any other source of discomfort (1). At first consideration, this discomfort may seem trivial in comparison to the risks of the pandemic, but this discomfort has been associated with a unwillingness by health care providers to wear isolation masks for the duration of an 8 hour shift even with scheduled breaks (2). This discomfort may potentially decrease compliance with institutional guidelines even among a population of highly educated and motivated providers.

A common source of this discomfort is due to prolonged contact and friction between sensitive skin and the straps of the masks. Many commonly used mask designs are secured by elastic straps looping around the posterior auricular region. This constant pressure and friction against the skin may contribute to increased wearer pain, irritation, and discomfort. The purpose of this work is to report a modified 3D printed mask extender to alleviate discomfort and increase mask wearability by relieving posterior auricular pressure from isolation masks.

Materials And Methods

Our institutional review board designated this project as non-human research and exempt. As part of resourcing 3D printing laboratories along with individual 3D printers to provide resources to healthcare workers, mask extenders were printed to relieve posterior auricular pressure from individuals wearing isolation masks. A freely available online template was used initially (3). Based on initial feedback the size was too small for some individuals. One of the authors, experienced in computer design, 3D modeling, and 3D printing technology (1 year of experience), modified the mask extender design (Fig. 1). This design is greater in length with accompanying peripheral rungs for isolation mask securement. The author's modification is available in the supplemental material (**Supplementary Materials STL files 1 and 2**). 3D printing was performed with Ultimaker S5 (Ultimaker B.V.; Geldermalsen, Netherlands) and CR-10 (Creality3D; Shenzhen, China) 3D printers using polylactic acid filaments. The author's modified extended mask extenders were printed and freely delivered to healthcare workers (physicians, nurses, technologists, and other personnel) at the authors' institution.

Results

The final mask extender design was printed with the two 3D printers with a maximum 7 straps printed simultaneously on each 3D printer. Mean print times ranges from 105 minutes for the Ultimaker S5 printer

and 150 minutes for the CR-10. At writing, 475 mask extenders have been printed, each delivered in batches of 50 extenders with requests for continued production. Through providers were not formally surveyed, direct feedback has been overwhelmingly positive. The demand far outweighs the supply and rate they are able to be produced.

Discussion

Although isolation masks are associated with less discomfort compared to N95 respirators, a prior study demonstrated that healthcare providers' discomfort increases with prolonged use (greater than 2 hours) of wearing isolation-type masks with ear loops and that the discomfort continues to increase on a per-hour basis (2). The mask extender design allows for isolation masks to be secured behind the posterior aspect of the pinna without exerting direct pressure on it, diffusing that pressure broadly across the posterior aspect of the head. This design, first posted online to the National Institutes of Health 3D Printing Exchange (3), has been modified by the authors by lengthening it and adding additional rungs to increase comfort and increased ability to adjust the tension of the straps to achieve a more individualized fit. The combined relief of pressure with tension control decreases discomfort and irritation from mask designs with ear loops. As mask utilization continues to increase among healthcare providers in every setting and among the lay public, this is especially relevant as increasing wearability and decreasing discomfort may increase compliance with the infection control and public health guidelines put forth by local and national institutions.

This design is part of a larger movement of community generated 3D printed solutions to novel issues that arose with the advent of this pandemic including ventilator components, supply chain shortages, personal protective equipment such as splash-proof face shields, surgical masks, N95 masks, N90 masks, powered air-purifying respirator hoods, and controlled air purifying respirator hoods, and environmental solutions such as door handle modifications (4). 3D printing has attempted to solve this issued by facilitating manufacturing of ad hoc personal protective equipment as well as medical equipment during the COVID-19 pandemic (5–7). These efforts have included producing face shields⁵, innovative ventilator solutions (6), among others. The FDA have issued caution with 3D printed personal protective equipment (7), but they have expressed willingness to work with individuals and entities producing such alternatives and are currently working with the NIH 3D print exchange (7).

Limitations to this work include obtaining formal survey data from wearers and comparing user comfort or discomfort levels compared to not wearing a mask extender. Similar interventions in the 3D printing of face shields for interventional radiologists have been thoroughly evaluated and found to not produce any detriment to ability of physicians to perform their duties while solving the supply chain shortage of personal protective equipment (8). For the mask extender design, the anecdotal support and metrics of satisfaction, including personal feedback and requests to produce more mask extenders, have been overwhelmingly positive, and the authors of this study thought it appropriate to share these results to offer this solution to a broader audience as well as encourage continued utilization and modification of 3D printed solutions as the world continues to grapple with the COVID-19 pandemic.

In conclusion, the authors offer a modification of a 3D printed mask extender design that decreases discomfort and increases the wearability of isolation mask designs with ear loops thought to relieve posterior auricular skin pressure and ability to control strap tension. The design is simple, produced with inexpensive material (polylactic acid), and have been well-received by healthcare providers at our institution. The authors offer their design, which others may adapt.

Abbreviations

National Institutes of Health (NIH)

Food and Drug Administration (FDA)

Declarations

Ethics approval and consent to participate: Our institutional review board designated this project as non-human research and exempt.

Consent for publication: Not applicable

Availability of data and materials: The datasets during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: All authors declare no potential conflicts of interest. None of the authors has any relationship with StratasyS.

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Design: ZOC, DH, PS, DHB

Experiments: ZOC, PS

Analysis of data: All authors

Guarantee of study: DHB

Initial draft: ZOC, JAM, CG, DHB

Critical revisions: All authors

Approval of final manuscript: All authors

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Figures

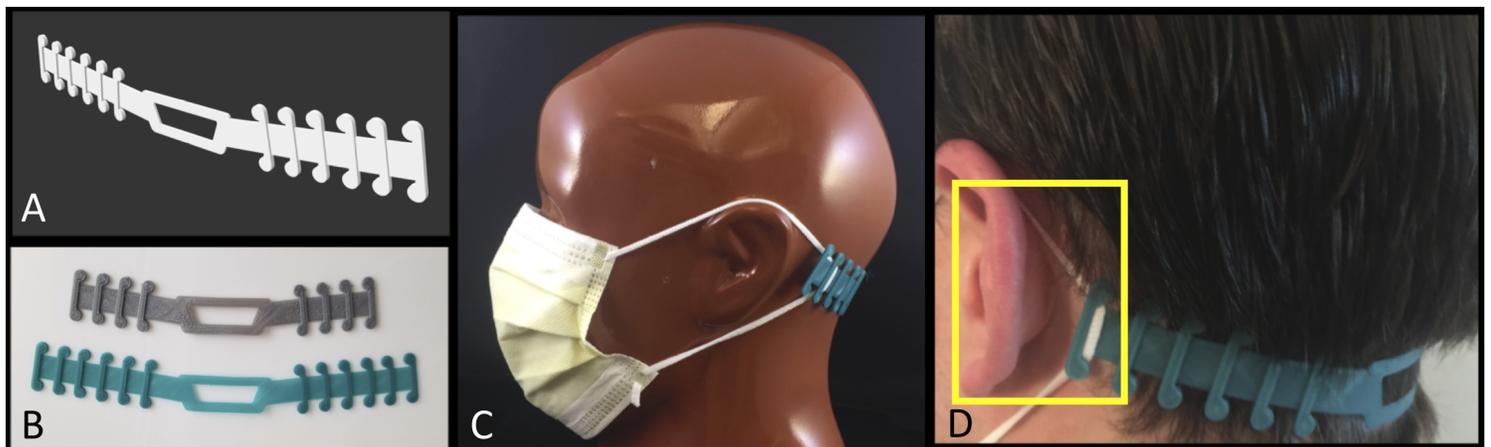


Figure 1

A. Stereolithography image file of the authors' modified mask extender design. B. Photograph of 3D printed mask extender from NIH 3D Print Exchange (3) (top, shorter design) and the authors' modified and extended design (bottom, longer design). C and D. Photographs of the lengthened mask extender on a head mannequin (C) and healthcare professional (D). Note that the extender holds the mask ear loop off of the posterior auricular surface (yellow box in D).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [ExtendedStrapV2.stl](#)
- [ExtendedStrapV1.stl](#)