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3D printing of frames for anti-coronavirus face shields using different processes and materials

E. Westphal[1*], R. Mau[1], T. Dreier[1] and H. Seitz[1,2]

[1] *Chair of Microfluidics, University of Rostock, Rostock, Germany*
[2] *Dept. Life, Light & Matter, University of Rostock, Germany*
[*] *Corresponding author, email: erik.westphal@uni-rostock.de*

Abstract: Due to the rapid spread of the novel coronavirus SARS-CoV-2 (COVID-19), medical protective equipment is in high demand. In order to cover the need for these protective materials, frames for face shields, for instance, can be produced flexibly, quickly and decentrally in small quantities through 3D printing. In this study, Fused Deposition Modeling (FDM) is used for the production of corresponding components from Polylactide plus (PLA+) and Polyethylene terephthalate glycol (PETG) material. Stereolithography (SLA) is also used to produce high-quality frames from a photopolymer. The frames are presented and examined with regard to their manufacturing technology features and surface properties.

I. Introduction

The novel coronavirus SARS-CoV-2 (COVID-19) is spreading uncontained all over the world [1]. COVID-19 is transmitted from human to human through close contact with an infected person via suspended droplets which are produced through coughing, sneezing or breathing and are absorbed through the mucous membranes of another person's mouth, nose and eyes [2][3]. The use of medical protective equipment (e. g. face shields) is therefore essential when dealing with infected people, especially for healthcare workers [4]. A face shield is a medical eye and face protection that protects against splashes, body fluids or potentially infectious materials. It is typically made of plastic and covers the eyes and face of the user [5]. A face shield, in combination with additional protective equipment (goggles and face masks), lowers the risk of infection of COVID-19 and also reduces the contamination of the respiratory protection [6]. Due to the COVID-19 pandemic, there is currently a worldwide shortage of medical protective equipment in many regions [4]. To counteract this situation, new production capacities for the production of these protective agents must be undertaken. For this purpose, a relaxation of the less essential regulatory requirements is proposed, so that, e. g. face shields can be made from materials that are classified as harmless when in contact with skin [6]. Thus, frames for face-shields can be produced, for instance, by using 3D printing. Through the wide spread use of 3D printers, rapid on-demand production of face shields can be carried out by a high number of users of 3D printers [6].

This study focuses on the comparison of frames for face-shields, which were 3D printed using Fused Deposition Modeling (FDM) with biocompatible thermoplastics and Stereolithography (SLA) with a liquid photopolymer. Particular attention is paid to the manufacturing technology features and the surface properties of the 3D printed frames.

II. Material and methods

A uniform design was chosen for the frames of the face-shields ([7], Fig. 1).

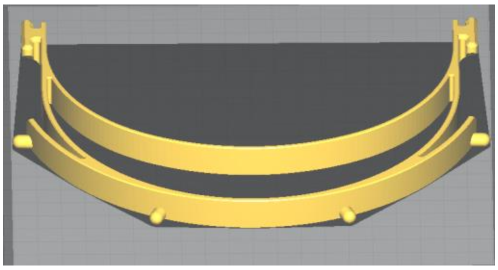

Figure 1: Open source CAD design of the face shield frames used for 3D printing

The frames were printed using an i3 Mega low-cost FDM printer (Anycubic Technology Co., Ltd, Shenzhen, China) and a material-specific Vector 3SP SLA system (envisionTEC GmbH, Gladbeck, Germany). Optimal process parameters were utilized for printing. The computer aided design (CAD) file was sliced using Cura software (version 4.4.1) for i3 Mega device and using Perfactory software (version RP 3.2.3520) for Vector 3SP device. For frames printed by using the FDM process, polylactide plus (PLA+) and polyethylene terephthalate glycol (PETG) filaments (Filamentworld, Germany) with a diameter of 1.75 mm were utilized. PLA+ is a common FDM material to be used for simple applications. PETG is very promising for medical applications owing to its biocompatibility [8]. The layer thickness was 0.2 mm in each case, the print speed was 50 mm/s and the filling density was set to 15 % using a grid filling pattern. The printing temperature was 200 °C for PLA+ and 220 °C for PETG parts. The build platform of i3 Mega enables the manufacturing of one frame per print job. The E-Clear material (envisionTEC, Gladbeck, Germany), approved for the Vector 3SP, was chosen for frames printed using SLA.

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The printing resolution in XY-direction and the layer thickness was 100 µm. The exposure speed was 9 mm/s. In comparison to the i3 Mega device, the Vector 3SP has a larger build platform which enables the manufacturing of two frames simultaneously. After the printing process post-processing is needed. Support structures as well as remaining liquid photopolymer has to be removed manually via cleaning in an isopropanol bath. In addition, there is the need for a 2x2 minutes post-curing process in a UV light curing box (envisionTEC, Gladbeck, Germany) at ambient temperature to finish the polymerization process.

III. Results and discussion

Frames made of PLA+ could be printed without any problems (Fig. 2 A). The printing time per frame was about 2 hours and 47 minutes. The material consumption was about 31 g (material costs of approx. €1.08). The print quality of the frames is good. The components have a closed surface without major irregularities. Post-processing could be carried out manually by hand with minimum effort. The surface quality is typical for FDM processes. The characteristic stair-stepping effect is partly visible. The frames are stable, very inexpensive to manufacture and roughly comparable to the cost of a conventional face shield. Frames made of PETG were difficult to print to an acceptable quality (Fig. 2 B). The printing time per frame was 2 hours and 48 minutes. The material consumption was about 36 g (material costs of approx. €1.26). This is only slightly higher than the cost of the PLA+ part. With the selected settings, the print quality of the frames is insufficient compared to the PLA+ parts.

The PETG frames show many strings of plastic and other imperfections that had to be removed mechanically with sandpaper. As a result, the surface quality is worse than that of the components made of PLA+ and contamination with abrasive particles occurs. However, the frames made of PETG are very flexible though strong, which could be beneficial for wear comfort. For both materials PLA+ and PETG common high temperature steam sterilization can be critical and low temperature sterilization techniques should be preferred [6][8]. The long-term resistance to manually cleaning procedures utilizing disinfecting solutions should be focused on in further studies.

Frames made from the E-Clear photopolymer could be printed with a very high accuracy (Fig. 2 C). The pure printing time of the print job of two frames took 2 hours and 55 minutes. The material consumption was 60 ml (material costs per frame of approx. €10.50, which is a factor of 10 higher than for FDM parts). There are photopolymers available on the market, which are significantly cheaper. However, only photopolymers approved by envisionTEC can be processed. Furthermore, there is the need for the described post-processing before the frame is ready for use. Nevertheless, the quality of the frames is high. They show smooth surfaces without significant defects. As a result, such frames may be easier to clean than FDM-printed frames. The SLA-printed frames are solid but flexible enough to offer a high wear comfort. The water-resistant material E-Clear withstands solvents such as isopropanol, which could be beneficial for quick cleaning procedures. The resistance to high temperature steam sterilization as well as adequate biocompatibility should be investigated in further studies.

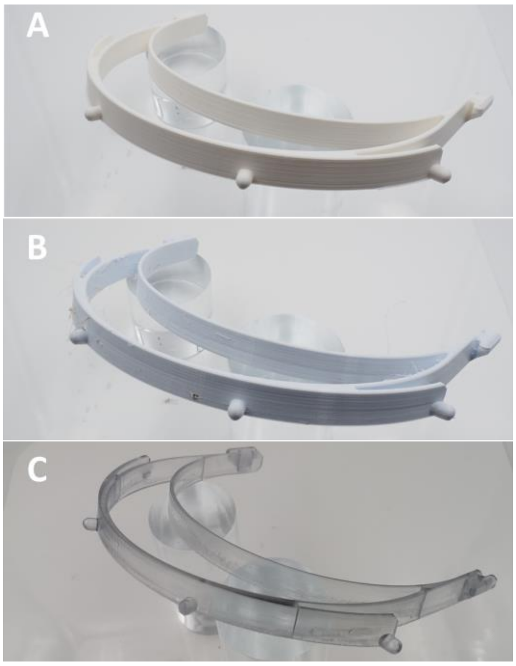

Figure 2: 3D printed frames using different materials and processes. A: PLA+, FDM; B: PETG, FDM; C: E-Clear, SLA.

IV. Conclusions

3D printing of frames for anti-coronavirus face shields was demonstrated utilizing a simple, open access CAD design. FDM and SLA were compared as possible manufacturing processes. Both 3D printing technologies differ in process and available materials, so there are differences in print quality and material costs. FDM could be beneficial for ready-to-use frames with low production costs. SLA requires a post-processing, but offers a smooth and easy to clean surfaces. Further studies on process parameters, long term use with skin contact as well as specific regulatory requirements are necessary for well-founded statements regarding the use of 3D printed frames for anti-coronavirus face shields.

Author's statement

The Authors state no conflict of interest.

References

[1] JHU, *COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE)*, Johns Hopkins University, https://coronavirus.jhu.edu/map.html, accessed 05.05.2020.

[2] M. Adnan Shereen, S. Khan, A. Kazmi et al., *COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses*, Journal of Advanced Research, 24:91-98, 2020.

[3] Y.C. Wu, C.S. Chen, Y.J. Chan, *The outbreak of COVID-19: An overview*, Journal of Chinese Medical Association, 83(3):217-220, 2020.

[4] WHO, *Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages*, World Health Organization, Interim guidance, Apr. 2020.

[5] FDA, *Enforcement Policy for Face Masks and Respirators During the Coronavirus Disease (COVID-19)*, U.S. Food and Drug Administration, Apr. 2020.

[6] C. Wesemann, S. Pieralli, T. Fretwurst et al., *3-D Printed Protective Equipment during COVID-19 Pandemic*, Materials, 13: 1997, 2020.

[7] fratzinger, *Covid- 19 Shield v18 80-80-80*, github.com, https://github.com/fratzinger/face-shield/tree/master/stl, accessed 05.05.2020.

[8] O. Oth, C. Dauchot, M. Orellana et al., *How to Sterilize 3D Printed Objects for Surgical Use? An Evaluation of the Volumetric Deformation of 3D-Printed Genioplasty Guide in PLA and PETG after Sterilization by Low-Temperature Hydrogen Peroxide Gas Plasma*. TODENTJ 13(1): 410–417, 2019.