Using 3D Printed PPE and Medical Supplies: 
A Primer for Healthcare Professionals

N95 Working Group Report

The COVID-19 Healthcare Coalition is a collaborative private-industry response to novel coronavirus. Our mission is to save lives by providing real-time learning to preserve healthcare delivery and protect populations. [https://c19hcc.org](https://c19hcc.org)
Using 3D Printed PPE and Medical Supplies: A Primer for Healthcare Professionals

Summary

Note: This report provides guidance to healthcare professionals who are considering whether to use 3D printed personal protective equipment (PPE) and medical supplies. It is a companion piece to “Health Guidelines for 3D Printing Medical Devices and Personal Protective Equipment During COVID-19 Response,” which is targeted to the Maker community and is available at www.c19hcc.org.

The COVID-19 pandemic has put tremendous pressure on medical supply chains. When authorized PPE is not available to healthcare professionals, they must make decisions about using alternative equipment and/or sanitizing and reusing items intended for one-time use.

The Maker community is distributing 3D printed (3DP) items that can help fill the gap, including masks, face shields, and other items. There’s a wide variety of possibilities, and if you are considering using 3D printed equipment, you need data to make a decision. For example, discover:

- What level of protection from SARS-CoV-2 will this item give my team and me?
- What is it made of and how it was made?
- Can I reuse the item and, if so, how many times?
- If the item is reusable, can I clean it with normal cleaning methods for medical protective equipment?

Consider These Frequently Asked Questions

These FAQs provide much of the information you will need to make appropriate decisions about using 3D printed items.

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Will the 3D printed item protect my staff, my patients, and me against particles containing SARS-CoV-2?

**Why should I care?** An ill-fitting item may provide a false sense of security and endanger you, your team, and your patients.

**What is the bottom line?** Make sure the item meets your basic fit and function requirements. Before going into a real-life situation, put on the equipment and practice the activities you will perform at the expected intensity levels. If the item compromises your ability to perform your job, do not use it.

**What else should I know?** As a healthcare professional, you are in control of this decision. You must be satisfied that the item will perform as advertised. Consider the following:

- **Fit:** Does the item make an adequate seal (e.g., against the face, in mating with another piece of equipment)? Does the item obstruct your vision? Does it inhibit communication? Does it allow sufficient airflow when you are working and moving quickly?
- **Function:** Do you have to modify your procedures to use the item? Does it help you do a job better? Worse? The same? Is it rigid enough? Does it flex where intended? Can it stand up to your expectations for time of use, e.g., a full shift? What is the expectation for the item’s ability to filter harmful particles?

Is the 3D printed PPE or medical device design approved by the FDA or NIOSH?

**Why should I care?** The Federal Drug Administration (FDA) and National Institute for Occupational Safety and Health (NIOSH) have formally vetted all the PPE you traditionally use. These two organizations ensure that the equipment is safe for patients and providers, performs its intended function, and will stand up to the rigors of the environment for which it’s designed.

**What is the bottom line?** At the time of this writing, no 3D printed PPE design has been NIOSH-certified or FDA-approved for use by healthcare workers. The choice to use equipment produced via 3D printing is something that you and your stakeholders must discuss after considering the information provided in this report.

**What else should I know?** The National Institutes of Health (NIH) is maintaining a repository of 3D printed designs that they have reviewed for clinical and community use during the nation’s fight against COVID-19: [https://3dprint.nih.gov/collections/covid-19-response](https://3dprint.nih.gov/collections/covid-19-response). Before the pandemic, neither the NIH nor FDA had pursued 3D printing PPE for daily use in medical applications, except in some very specialized activities focused on the manufacture of custom implants and similar applications. The previous caution was due to the difficulties associated with producing thousands or millions of copies of an item using 3D printing.

Should I use an item that is not based on a clinically reviewed design?

**Why should I care?** Many Makers have the basic skills to develop and post designs online. However, the Maker trying to help you may not understand the considerations a new entrant in
the market undergoes during the vetting and approval processes, particularly when it comes to PPE and other items intended for use in clinical settings.

**What is the bottom line?** It is best to select a design that has been evaluated for use in clinical settings by clinicians for the particular application you intend. You can find designs that are labeled “Reviewed for Clinical Use” and “Optimized for Community Use” on the NIH 3D Print Exchange website. Designs resulting from partnerships of Makers and local healthcare outlets may also be acceptable if that healthcare facility has tested the design in a clinical setting. That facility should be able to provide its professional evaluation in these cases. The Maker should be able to point you back to the source of the design it used to print the items and describe the level of vetting it has received by healthcare providers.

**What else should I know?** If Makers offer unique designs that seem to have merit for a specific emergent need and you have the time and resources, you may decide to form a local partnership with your Maker counterpart to vet a solution for your needs. You should also conduct a survey of previously developed designs already vetted by NIOSH or the FDA. In the end, you, lead in this relationship because you must shoulder the risk associated with a particular approach. That said, many of the vetted designs began with this type of collaboration between Makers and healthcare workers.

**What 3D printing method did the Maker use to create the items?**

**Why should I care?** Each printing process has pros and cons that may be unique to the PPE context. For instance, depending on the printing method, the item’s surface will be more or less conducive to harboring bacteria and other particulates. Some printing processes use caustic chemicals, while some printed materials may degrade under prolonged exposure to ultraviolet light.

**What is the bottom line?** An item printed using Fused Deposition Modelling, or FDM, the most common form of 3D printing for hobbyist Makers, has natural crevices between layers that can harbor bacteria and other particulates. This affects your ability to sanitize FDM items. Makers can mitigate this liability by applying a clearcoat or other post-printing treatment. See “Does the item have any kind of clearcoat or epoxy?” below. This treatment may be an acceptable risk for certain applications.

Items printed with a stereolithography (SLA) printing process, though less common in the hobbyist community, have a smoother surface and will be less prone to harboring bacteria and other particulates without a clear coat. However, the SLA printing process makes use of caustic chemicals that must be cleaned away before you can use the item. Also, prolonged exposure to ultraviolet light weakens or breaks most SLA items.

Do not assume that 3D printed items are watertight. If it has a complete clearcoat or epoxy covering, it is much more likely to be watertight.

**What else should I know?** FDM items can be porous depending on the individual printer settings. SLA items have much smaller layer heights, so their surfaces are smoother and more conducive to cleaning and sealing.

If a 3D printed item is intended to serve as a vapor or liquid barrier, ask the Maker how they printed it. Ideally, it should be solid rather than partially filled with a honeycomb or grid pattern, as is sometimes done in 3D printing to save material or reduce print time. Inspect the item for
visible pores and gaps. Understand that these may still exist at a microscopic level even if you are unable to see them.

**What material did the Maker use to print the item and will it hold up to what I want to use it for?**

**Why should I care?** The item’s material is directly related to its biocompatibility, function, and ability to stand up to standard wear, tear, and cleaning.

**What is the bottom line?** Consider how you plan to clean the item. Find out what material the item is made from and, using Table 1 below, determine whether it can withstand the rigors of your cleaning process. Will the 3D printed material make contact with your skin, particularly around your eyes, nose, or mouth?

**What else should I know?** 3D printers and materials that are certified for medical use or biocompatibility are typically too expensive for hobbyist Makers. Consider the following guidelines:

- For PPE, do not use items printed from materials that have additives, such as carbon fiber or metal, unless they are explicitly certified for skin contact. These particles may cause skin irritation or shed from the item, risking the possibility that you will inhale or ingest these particles if they are in close proximity to your nose or mouth. There are some skin contact-certified 3D printing materials with metal additives, but these are exceptions and not common for hobbyist-Makers.
- For FDM-printed items, the material of the nozzle through which the hot plastic is extruded makes a difference given that soft nozzle materials, like brass, may add trace amounts of heavy metals to the finished item. Items produced with a stainless steel or other hard nozzle material mitigate this risk.
- Some dyes are not biocompatible. If possible, limit the use of dyes if the items will be in contact with skin.
- A biocompatible layer, such as moleskin, placed between the item and the skin can mitigate some biocompatibility concerns.

Table 1 summarizes common types of 3D printing materials and their efficacy for healthcare purposes. Consider your use in light of these characteristics.
Table 1. Properties of Common 3D Printing Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum Temperature*</th>
<th>Basic Characteristics</th>
<th>Biocompatibility</th>
<th>Cleaning Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>60-65°C. Do not sanitize with heat.</td>
<td>Good all-purpose FDM printing filament.</td>
<td>Additives may not be biocompatible.</td>
<td>Alcohol and solvents will degrade item.</td>
</tr>
<tr>
<td>ABS</td>
<td>105°C</td>
<td>Structurally tougher than PLA.</td>
<td>May present uncomfortable or irritating odors. Additives may not be biocompatible.</td>
<td>Most resistive to breakdown from alcohol and solvents.</td>
</tr>
<tr>
<td>PETG</td>
<td>80°C</td>
<td>Good middle ground between heat resistance of ABS and ease of print of PLA.</td>
<td>Additives may not be biocompatible.</td>
<td>Alcohol and solvents will degrade item.</td>
</tr>
<tr>
<td>TPE/TPU</td>
<td>Do not apply heat.</td>
<td>Can print flexible items.</td>
<td>Additives may not be biocompatible.</td>
<td>Alcohol and solvents will degrade item.</td>
</tr>
<tr>
<td>SLA Resins</td>
<td>Varies with brand.</td>
<td>SLA items are generally smoother than their FDM counter items.</td>
<td>Resins may not be biocompatible.</td>
<td>Sensitivity to ultraviolet light for most resins.</td>
</tr>
</tbody>
</table>

*These are general guidelines for material properties, and properties may vary slightly among brands.

For more information on material properties of specific items, such as temperatures and material additives, you can consult the material’s safety data sheet.

**Does the item have any kind of clearcoat or epoxy?**

*Why should I care?* A clearcoat or epoxy covering can make the item more resistant to harboring bacteria and may also render the item watertight. It may also provide a layer between the item and your skin to reduce irritation or odors.

*What is the bottom line?* When water or airtightness is critical, items covered with clearcoat or epoxy are preferable provided that the clearcoat or epoxy does not cause biocompatibility issues.

*What else should I know?* There are some certified biocompatible epoxies, but these are not as common or accessible as other types. Determine the exact type of epoxy used and consult the safety data sheet for risks associated with the epoxy when it is dry. Note that heat and chemical resistance of the epoxy affect which cleaning methods can be safely used.
Did the Maker use any other materials or glues to finish the product?

**Why should I care?** As with epoxies, glues may not be biocompatible and may affect other aspects of use and cleaning.

**What is the bottom line?** Make sure you understand which additional materials the Maker used to assemble this item, how the materials contribute to the function of it, and how they affect the ability to easily sanitize the item for repeated use.

**What else should I know?** The Maker may have used a repurposed material like weather stripping to create a seal against skin in a 3D printed mask. These materials and glues may not tolerate the same cleaning processes as the 3D printed items themselves. Remove weather stripping, moleskin tape, elastic, and glues that won’t survive those cleaning procedures before disinfecting the 3D printed items and replace them with fresh material afterwards.

Where did Makers build the items, and how did they handle them?

**Why should I care?** To ensure healthcare workers are not exposed to infection from using a locally made 3D printed item, Makers must exercise reasonable measures of cleanliness as they produce these items.

**What is the bottom line?** Verify the steps taken by the Maker to sanitize the printing area and the raw materials involved in the print.

**What else should I know?** Below are a few questions that you can use to diagnose the level of care a Maker took in this area.

- How did the Maker sanitize the general activity area and the 3D printer? Note, due to the high heat involved in the FDM 3D printing process, the feedstock materials don’t require sanitation ahead of time. The act of printing has the effect of pasteurizing the material.
- Did the Maker wear PPE in order to ensure the cleanliness of the activity area and printed item?
- Did the Maker handle and pack 3D printed items with cleanliness in mind? Did they exercise cleanliness in how they stored packaging materials prior to use?

Develop a working relationship with well-meaning Makers that enables mutual trust and respect in this critical area.

How can I clean 3D printed items?

**Why should I care?** 3D printed items can harbor bacteria and other contaminants in the small crevices between printed layers. Many standard sanitization processes for medical use involving heat, ultraviolet light, or chemicals may destroy 3D printed items or other materials used in the assembly of 3D printed PPE.

**What is the bottom line?** Consider the required cleanliness level for your application alongside the impact those cleaning options will have on the item. Parts with rough surfaces are difficult to
clean with wipe-down methods. Characterize the impacts of these shortfalls as you put the item through these cleaning cycles to ensure that it continues to support your need in terms of function and safety.

What else should I know? The finish of a 3D printed item using an FDM printing process is naturally rough, which may allow microbes to flourish inside the surface features and small crevices characteristic of FDM-printed material. SLA items typically have thinner layers, resulting in smoother items that are easier to clean.

The Prusa 3D printing company has provided information on specific cleaning methods in its Prusa Face Shield Disinfection guide. The list below summarizes key information from that guide.

The following concerns are associated with standard medical disinfection techniques:

- **Chemical Disinfection.** Submerging 3D printed items in isopropyl alcohol of 70% or greater concentration for 5 minutes has been shown to be effective in sanitizing them. Diluted bleach solutions are also effective. However, repeated submersion in cleaning solutions may weaken 3D printed items and may also increase the porosity of the item. Examine the item for brittleness or flexibility changes before using again.

- **Sanitization with Heat.** When you use heat-based disinfection methods, pay careful attention to the maximum temperatures listed in Table 1. Also consider the maximum heat any glues, coatings, and soft materials in the item can withstand.

- **Ultraviolet Germicidal Irradiation (UVGI).** The effects of a high dosage of ultraviolet light such as that used in UVGI disinfection treatments is not known for all 3D printable materials. SLA resins are typically very sensitive to ultraviolet light. Parts printed in SLA should not be sanitized with a UVGI-based method. Additionally, 3D printed items may possess complex geometries that will shadow regions of the item from the ultraviolet source, resulting in inconsistent exposure.

- **Replace Fragile Materials.** For items that rely on additional materials like weather stripping, moleskin tape, elastic, and glues that will not survive standard medical decontamination procedures, remove and replace fragile materials before disinfecting items and replace them with fresh material before using again.

The Decision Is Yours

You, the potential user of this equipment, control the narrative around the use of 3D printed items. It is up to you to weigh the risks against urgent needs. The CDC has published guidance that the use of PPE from nonstandard sources is permissible in cases where PPE from traditional sources is not available. This guidance, coupled with a deliberate operationally based risk assessment, should inform every decision you make about using PPE or other medical devices from nontraditional sources. Once supply chains can provide FDA-approved items again, discontinue use of Maker-made items. For further information, see the first resource in the section below.

For more information and sources, refer to MITRE’s companion paper: Health Guidelines for 3D Printing Medical Devices and Personal Protective Equipment During COVID-19 Response.
Additional Resources

- FDA FAQs on 3D Printing of Medical Devices, Accessories, Components, and Parts During the COVID-19 Pandemic
- NIH 3D Print Exchange
- CDC COVID-19 Page
- EPA List N: Disinfectants for Use Against SARS-CoV-2
- America Makes: Fighting COVID-19 with 3D Printing
- COVID-19 Healthcare Coalition
- Prusa Face Shield Disinfection (compiled list of disinfection techniques tested on a particular 3D printed item)