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COVID- 19 Crisis- A paradigm shift in the development of Facemasks

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Abstract : Recently all the global healthcare systems are menaced by novel COVID pandemic. With the prolong increasing rate of infection there was also increase in demand for clinical equipment like gloves, mask, ventilator and valves. Suppliers and manufacturers weren't able to meet up the spike in demand. Various 3D printing startup companies pitched in their technology to dispose off this strain. Three-dimensional printing technology entails manufacturing technique to build a structure of any imaginable shape. This technology has revamped medicinal arsenal. In this article we had outlined an edge that 3D printing mask holds over conventional or cloth mask. We have also noted down different type of 3D printed mask available like copper 3D printed, ViriMask and silicone cast. Our studies helped us to infer that 3D printing with its new trend in healthcare has led a manufacturing renaissance and a shield to fight against COVID crisis.

Keywords: COVID-19, 3D printing, Facemask, 3Dprinted Facemask, Conventional mask

1. Introduction

3D printing or three-dimensional printing is a process in which 3D objects are produced by fusing in material like ceramic, plastic, metal or even living cells. With this technology we can produce object of any imaginable shape or size using computer aided designs (CAD). 3D printing has revolutionized healthcare sector by expanding it medical application, which are both potential and actual.[1] There are several evidence of wonders 3D printings has done they include anatomical model, implants, customized prosthetics and tissue fabrication. It was apparently found that 3D printing has upper hand in medicines as they include benefits like cost effectiveness, increase productivity, personalization and customization of medical equipment, products and drugs. Today, world is facing is worst nightmare in form of Corona virus- A pandemic which apparently challenge global healthcare system. With everyday spike in infection rate huge strain on healthcare system is inevitable. It is reported that hospitals are running out of stocks for essentials like masks, ventilator, gloves and valves as supplier aren't able to deliver in require timeline.[2] 3D communities are volunteering resources and time for life-saving supplies like oxygen valve, mask, shields and ventilator. In this article we had elaborate on 3D printed mask, providing its benefits over conventional and its widespread application.[3]

2. Conventional Facemasks and its drawbacks

A sudden shortage of facemasks has been observed due to the COVID-19 pandemic. The increasing global demand is resulting in companies running out of masks. As a consequence of this, people are preparing their own masks from the old clothes available (Figure 1). A study conducted by University of Massachusetts Amherst last year showed that cloth masks can protect particulate matter of 2.5 um only marginally. They are capable of removing only 15% of particulate matter emitted from diesel combustion. Hence, a false sense of security is provided by such masks. A most common type of conventional masks is the surgical mask which has the capacity of blocking the physical particles but not necessarily the airborne particles (Figure 1). There is a problem with conventional masks is that a

high viral load could be trapped within millimeters of our nose at the end of the day, hence chances of exposure to deadly microbes increases.[11] Surgical masks are used to prevent large droplets splashing out from person's mouth. Also masks with filters such as N95 and N99 shows efficiency only when worn properly to remove particles of 0.3 microns or larger with filter capacity of 95% and 99% respectively (Figure 2). N95 and N99 masks has been used usually to combat infections like tuberculosis and it has been observed that they can block particulate matter only when air- leaks are prevented properly. A good fit of facemask may be hindered by different facial structures, beards or facial hair because of which contaminated air would be let in. Moreover, these N95 and N99 masks that are particulate specific provide no or ineffective protection against gases such as carbon monoxide, sulfur dioxide, nitrogen dioxide that are responsible for intoxicating the lungs and causing asthma and irritation to eyes.[6] According to United States Food and Drug Administration (USFDA), the surgical masks that are designed provide poor protection from the microbial germs as well as other contaminants because of their loose fit. Furthermore, these conventional masks are single used devices that are required to be cautiously disposed. Hence, its demand increases tremendously in such time of COVID-19 crisis. Modification of N95 masks can be used to expand its lifetime using 3D (3 dimensional) printing technology. 3D printing is expected to revolutionize the healthcare system and expand its horizons for medical applications.[10]

(a) (b)

Figure 1: (a) Homemade Cloth Masks.[7] (b) Surgical Mask.[8]

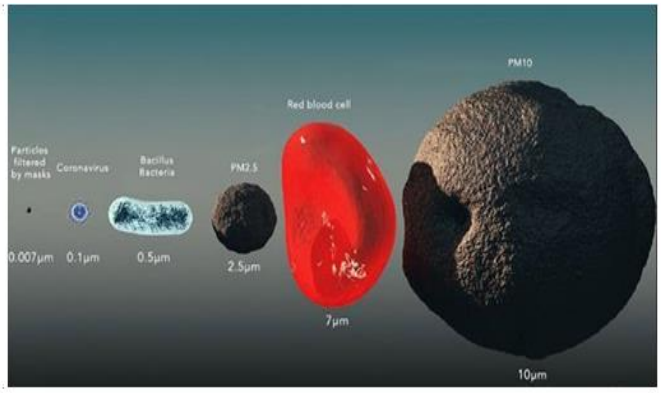
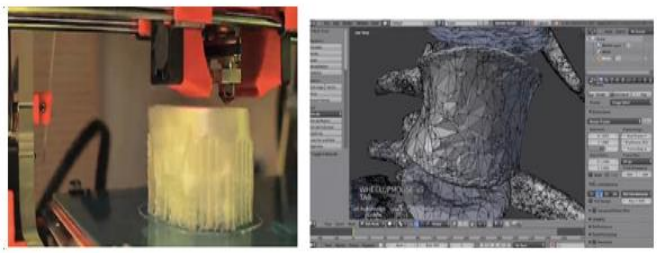


Figure 2: Image of Coronavirus vs other particles.[9]

3. Technology driven 3D Printing

3D printing has various advantages such as customization and personalization of medical products, equipment and drugs; increase in productivity; cost- effectiveness; fabrication of organ and tissue and many more. 3D printing was first coined by the famous scientist Dr. Charles Hull in the early 1918's as "Stereolithography". 3D printing is basically a method of manufacturing objects by material fusing or deposition- such as metal, ceramics, plastic, powder, living cells in a layered pattern to design 3D objects. Stereolithography uses an .stl file format to interpret the data in a CAD file, allowing these instructions to be communicated electronically to the 3D printer (Figure 3). The instructions in the .stl file (Surface tessellation language) may also include information such as the color, texture, and thickness along with the shape of the object to be printed.[12]



(a) (b)

Figure 2: (a)Instructions in a digital file used to create a physical object using 3D printing (b)Conversion of radiographic images to 3D print files for creation of customized medical, anatomical structures.[10]

In this time of COVID 19 pandemic where a lack of professional facemasks is faced by most healthcare worker around the globe. The potential solution to tackle this problem is to make facemask easily available, at low cost and high productivity which can be

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served by 3D printing to cope mass shortage. The rationale behind this is to develop and design reusable custom made three dimensionally printed facemask based on individual face scanning, 3D modelling and 3D printing that can be adopted for use worldwide.[12] It has been studied that 3D printed shields for N95 facemasks could help fight Clinicians fight COVID- 19. The concept is that it will help to improve the lifetime of N95 masks. These 3D printed masks shield when placed over N95 masks will act as a protective shield like covering and will limit the exposure of contaminants to N95 masks, thus increasing its lifetime beyond its typical onetime use. The early shields were printed using a thermoplastic polymer called acrylonitrile butadiene styrene. This polymer is flexible when subjected to high heat and on cooling forms tough, strong shell which fits nearly atop the N95 masks (Figure 3). A major advantage is that this mask shield can be manufactured in 40 minutes on the Qidi 3D printer which can be further reduced to 5 minutes.[6] As stated before, the major advantage of 3D printing is its cost effectiveness and speedy manufacturing capability. Reduced cost can be attributed to the decrease in the use of unnecessary resources and also the availability of wide variety of materials for 3D printing.[10] This technology is much faster than the traditional technologies which results enhanced productivity. Furthermore, there is wide variety of 3D masks available which is discussed further.

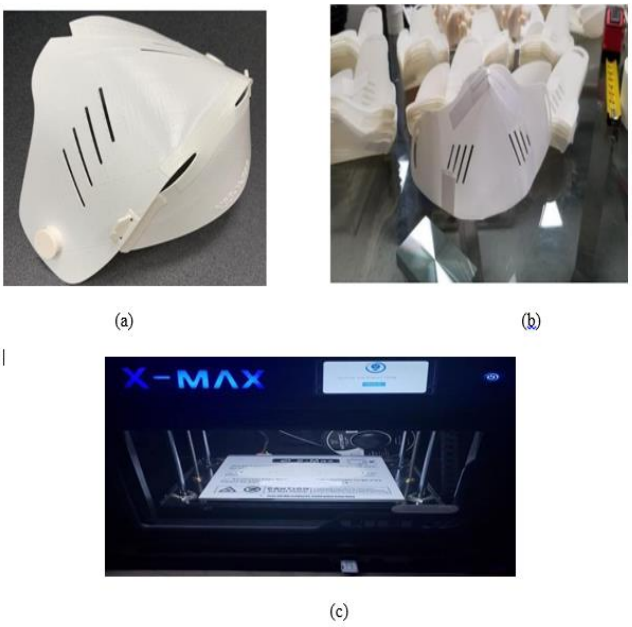

Figure 3: (a), (b) 3D Printed Shields for N95 Facemasks (c) N95 Mask Shield on the Qidi 3D Printer.[6]

4. Method of designing 3D Printed Facemask

First step for preparing 3D printed mask is 3D facial scanning which can be done using any smartphone or apps like Bella's 3D face app, available on play store. Then starts the modeling process assisted by CAD software, it includes templates of reusable components like face mask body and filter membrane support, connection of these two components are designed using screw fixation type which helps in tightening of mask after application. Boolean calculation is carried out between face scan and virtual templates using CAD designer so as to obtain best fit And accurate 3D face mask. Further 3D printing can be done using Polyamide composite or Selective Laser Sintering 3D printer. Once the reusable components are printed disposable components like filter membranes and head fixation bands are attached, thereby completing production of 3D printed mask. Disinfection of printed mask can be done by dipping it in a antimicrobial solution for about 15 minutes and then rinsing it of using cold water (Figure 4). [6]

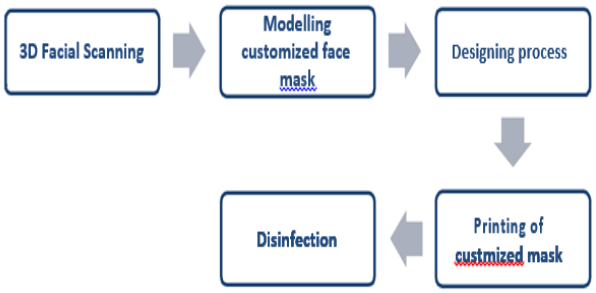

Figure 4: Schematic representation for development of 3D Printed Facemask.[6]

5. Types of 3D printed facemasks

Copper3D printed facemask-

A leading manufacturer of 3D printing materials Copper 3D recently published an STL digital file with open source of an N95 respirator that could be 3D printed and protect against Coronavirus. This initiative was named as “Hack the Pandemic” with the motive to reduce the lack of N95 or FFP2 for healthcare professionals around the globe. According to the company, this facemask is a Nano Hack 3D printed mask that is reusable and has the ability of producing antimicrobial, antiviral effect as it incorporates a fine modular filtration system containing copper

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oxide nano composite which is known to deactivate viruses along with a filtration disk to regulate particle size and air intake (Figure 5), (Figure 6). In order to allow massive shipping across the globe, this mask is designed in a flat pattern. NanoHack uses nano copper embedded in (non- woven propylene) which is the same material employed in surgical masks yet achieves a filtration efficiency of 96.4% for microbes of 1 micron and an efficiency of 89.5% for 0.02- micron sized microbes. [13] The active materials used for the manufacture of this 3D printed facemask is PLACTIVE® and MDflex® which are innovative nanocomposites formulated by Copper3D, PLA (Polylactide) and TPU (Thermoplastic polyurethane) of high quality which is scientifically patented by the company. PLACTIVE® (PLA based material) acts as a protective material by avoiding any harmful contact with the external environment and MDflex® which is an antimicrobial TPU acts as a seal and provides strong and hermetic Monoblock structure to the facemask. The property of this mask to be reusable and recyclable allows the mask to be used by the health professionals as many times as needed and avoids detrimental effect to the ecosystem.[13, 14]

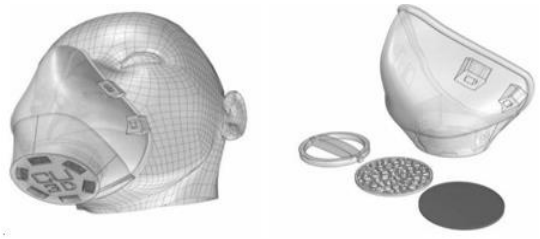

Figure 5: Copper 3D printed facemask.[15]

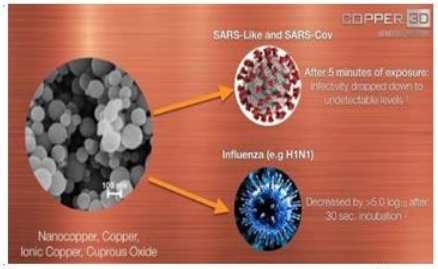

Figure 6: Copper Antiviral Activity.[15]

ViriMASK Protective Oculo- Respirator-

Eyes are a major point of entry for microbes such as viruses, bacteria but facemasks usually do not cover eyes. Scientists in Israel have developed a facemask more protective than an N95 (FFP 2) called the “protective oculo- respirator”. This mask employs 0.1-micron filter and should be replaced every 12 hours of use and a special envelope containing disinfectant should be used to dispose it. Furthermore, it can cover the entire nose, mouth and eye region unlike the N95 mask.[14] It is easy to disinfect and wash ViriMASK, provides personal comfort and minimum skin pressure for extended wear. This mask employs a filtering mechanism around the nose and mouth a see-through visor covering the eyes and is strapped around the head. It has a high filtration rate of protecting against 99.99% particles unlike N95/ surgical masks which has only 95% filtration rate. It provides exceptional ventilation with breathing area 5X larger, benefits by comfortable breathing due to low resistance to air flow (Figure 7).[16] Its main advantage over N95 masks is that it can provide protection against small viruses such as the Coronavirus, bacteria and environmental aerosols. and hence, prevent conjunctival contamination and inhalation of viruses.[17]

Figure 7: ViriMASK Protective Oculo- Respirator.[16]

3D printed silicone cast mask-

To tackle the needs of the healthcare workers during this pandemic, Barrow Neurological Institute came up with a N95 substitute. A 3D printed silicone cast mask employs a 3M P100 filter that can be worn with other existing PPE. PLA- 3D printing filament, Dragon Skin 10 Very Fast (Silicone), Sil- Poxy (Silicone Rubber adhesive), Ease release 200 (Silicon Mold release), Silc Pig (Silicone colorant), are the materials used for the design of this mask (Figure 8). The filters incorporated in this mask is approved by the National Institute for Occupational Safety and Health and is authorized by the USFDA for emergency use.[18]

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Figure 8: 3D printed silicone cast mask.[18]

6. Recent trends in 3D printing

3D printing technology stands as a pillar in manufacturing renaissance, especially in this prime battle against COVID-19. 3D printing projects with speedy manufacturing and cost effectiveness has bloomed in healthcare sector.

1. Italian firm designed 3D printed respiratory valves for hospital running out of valves for ventilator machine.

2. A factory in Ohio manufactures 100000 nasal swaps every day for COVID-19 testing using 3D printing technology.

3. Winsun, a 3D printing company based in China developed quarantine booths. These booths have their own electricity and water supplies, which tense to relieve stress in hospitals as well as patient crowding.

4. Proto labs a 3D printing service has collaborated with University of Minnesota for production of low-cost printed ventilator splitter which support multiple patients in single ventilator at a time.

Hopefully more supplies and manufacturer follow this lead and make life-saving equipment in this time of crisis.[5]

7. References

1. Mertz L. Dream it, design it, print it in 3-D: what can 3-D printing do for you? IEEE pulse. 2013 Nov 6;4(6):15-21.

2. Klein GT, Lu Y, Wang MY. 3D printing and neurosurgery--ready for prime time? World neurosurgery. 2013 Sep 1;80(3-4):233-5.

3. Schubert C, Van Langeveld MC, Donoso LA. Innovations in 3D printing: a 3D overview from optics to organs. British Journal of Ophthalmology. 2014 Feb 1;98(2):159-61.

4. Swennen GR, Pottel L, Haers PE. Custom-made 3D-printed face masks in case of pandemic crisis situations with a lack of commercially available FFP2/3 masks. International Journal of Oral and Maxillofacial Surgery. 2020 Apr 2.

5. The American Society of Mechanical Engineers. 8 Ways 3D Printing is helping to fight

Coronavirus. Mark Crawford 2020;15(March). https://www.asme.org/topics-resources/content/8-ways-3d-printing-is-helping-to-fight-coronavirus [accessed 16.05.20]

6. Rapid Response: 3D- Printed Shield for N95 Face Masks Could Help Clinicians Fighting Coronavirus. Scott Woolley 2020;2(April). https://www.ge.com/reports/rapid-response-3d-printed-shield-for-n95-face-masks-could-help-clinicians-fighting-coronavirus/amp/ [accessed 17.05.20]

7. Will homemade face masks keep you from getting sick with Coronavirus? What to know. Jessica Dolcourt 2020;1(May). https://www.cnet.com/how-to/will-homemade-face-masks-keep-you-from-getting-sick-with-coronavirus-what-to-know/ [accessed 17.05.20]

8. How to buy a mask that fits. Ministry of Health, Singapore; 2020 https://www.healthhub.sg/live-healthy/1509/how-to-buy-a-mask-that-fits [accessed]

9. N95 vs FFP3 and FFP2- What's the difference? Fast Life Hacks 2020;3(Feb). https://fastlifehacks.com/n95-vs-ffp/ [accessed 18.05.20]

10. Ventola CL. Medical applications for 3D printing: current and projected uses. Pharmacy and Therapeutics. 2014 Oct;39(10):704.

ISSN:-2581-6934 |Available at : www.jidps.com | pp :(8-13)

11. Bruce TA. Corona Virus Disease (COVID 19): Rapid human ingenuity through innovation and technology as a proactive and admirable response in the storm of a global pandemic.

12.Swennen GR, Pottel L, Haers PE. Custom-made 3D-printed face masks in case of pandemic crisis situations with a lack of commercially available FFP2/3 masks. International Journal of Oral and Maxillofacial Surgery. 2020 Apr 2.

13. Hack the Pandemic Copper 3D; 2020 https://copper3d.com/hackthepandemic/ [accessed 20.05.20]

14. Covid-19: Developing High Tech Productive Masks. Celia Sampol 2020;2(April). http://emag.medicalexpo.com/covid-19-development-of-high-tech-protective-masks/ [accessed 21.05.20]

15. 3D Printlife. 2020 https://www.3dprintlife.com/medical-grade-filament/plactive-an1 [accessed 21.05.20]

16. ViriMASK™. 2020 https://www.virimask.com/ [accessed 22.05.20]

17. New ventilator mask protects entire face from coronavirus. Abigail Klein Leichman

2020;15(March). https://www.israel21c.org/new-ventilator-mask-protects-entire-face-from-coronavirus/ [accessed 22.05.20]

18. Barrow Neurological Institute. 3D Printed N95 Replacement Mask. 2020 https://www.barrowneuro.org/get-to-know-barrow/barrow-innovation-center-2/3d-printed-n95-mask/ [accessed 23.05.20]

ISSN:-2581-6934 |Available at : www.jidps.com | pp :(8-13)