Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Research Letter

Purview of 3D printing in medical applications during COVID-19

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The global health care system has failed in checking the novel Coronavirus disease-2019 (COVID-19). The COVID-19 has exposed the vulnerability in the present health care system and policies that led to the current pandemic. The major flaws were related to the inadequate supply chain of life-saving medical equipment and their components including ventilators, diagnostic devices and personal protection equipment (PPEs) for the health workers. These flaws have emphasized the need for streamlining the global medical services, equipment manufacturing and supply units through the integration of proficient technologies. Besides, the reframing of health policies is essential for bolstering the basic medical facilities across the globe.

In recent years, there has been a huge impetus on 3-dimensional printing (3DP) technology. The inventors and innovators are heavily relying on 3DP technique that aids the fabrication of 3D objects with digitally created files. The 3DP has advantages of flexibility, creativity and ability for in-house, low-cost manufacturing and customization. With the advent of such innovative technology, we are standing at the doorway of endless possibilities. Therefore, it is imperative to apply this technical mammoth (3DP) for solving the COVID-19 riddles.

According to the guidelines of PRISMA-ScR, a literature survey was conducted to evaluate the scope of 3DP in COVID-19 scenario. In the search strategy, the paucity of literature on COVID-19 led us to substitution of term COVID-19 with "infectious diseases". We explored PubMed, Science Direct, and Google Scholar for the research and review articles published after the year 2015 (till May 18, 2020). Finally, the selected articles were tabulated and summarized according to the PICO (Refer to Supplementary Table). The ensuing text highlights the possible scope of 3DP in strengthening the medical services in the current scenario:

1 **Manufacturing of Medical devices/components**: Literature closely supports 3DP as an augmentation of the primary manufacturing units for the production of medical devices/components like Masks, PPEs, Ventilator Couplers, Respiratory Devices and Nasopharyngeal (NP) Swabs. Besides, the US National Institute of Health has provided a free 3DP Exchange platform that could be used to create, share and print 3D models, ventilators, respiratory components, masks, face-shields and other protective equipment (https://3dprint.nih.gov/collections/covid-19-response). Also, the US Food and Drug Administration (FDA) has adopted a moderate approach in provisionally approving all these items [1]. Considering the scope and versatility of 3DP, leading companies have stepped forward in manufacturing various specialized medical and protective equipment to meet the global demand during this pandemic.
2 **Laboratory setup/gadgets:** Designing diagnostic prototypes for the detection of infectious diseases could be achieved through Additive Manufacturing (AM) technology. The researchers [2] have been innovative in developing a prototyped ELISA 3D-well resulting in a 3-fold enhancement of test sensitivity. Similarly, through 3DP, various microfluidic-module based nucleic-acid purification, amplification and quantitative PCR (qPCR) devices have been developed for COVID-19 diagnosis as a cost-saving option [3]. Thus, 3DP has helped in rapid, sensitive, robust, and accurate diagnosis due to the reduction in dimension.

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3 **Point-of-care technology (POCT):** Through the unison of 3DP and microfluidics, the intricate laboratory test procedures could be advanced for mass-screening/testing. This is achieved by miniaturization of the test procedure into a compact module called point-of-care (POC) devices. To date, POCT based devices for the detection of *Salmonella* [4] and *Neisseria meningitides* in cerebrospinal fluid (CSF) and *Plasmodium falciparum* [5] in blood plasma using microbial genomic DNA (gDNA) have been developed. These diagnostic kits are affordable and have produced reliable, robust and conclusive results in a small-time window. Hence, 3DP has a definite scope in improvisation of coronavirus diagnosis in the near-future.

4 **Research:** Bioprinting, a branch of 3DP, offers 3D organoid models [6] and Organ-on-a-chip [7] model systems. The biological platforms are popularly used in studies involving assessment of the pathogenicity of the infectious agents, getting insights into the infection mechanism, evaluation of the drug toxicity and its efficacy on various organ models such as lung, gut and skin. These platforms could act as an ideal model system for an *in-vitro* study of novel coronavirus infection physiology and mechanisms as they are better than the traditional 2D cell culture approach and offers 3D space that closely replicate an *in-vivo* environment, thus providing real-time close predications.

5 **Controlled drug dosage and delivery systems**: Globally, 3DP has revolutionized the drug industry by accelerating the drug discovery and manufacturing [8] process, development of novel drug delivery systems [9] and the assessment platforms for individual dosage estimation system [10]. There has been a surge of interest in 3DP due to immense customization potential i.e. it can provide desired flexibility in terms of controlled drug dosage to an individual. Besides, regulated drug release in the body, specifically to a particular tissue could be achieved with intricate geometries. Intriguingly, the side effects of the drugs could also be minimized using individualized dosing delivery systems. Therefore, the 3DP has enormous scope in revolutionizing research and development of the COVID-19 drug and potential vaccine candidates. Besides, modulation of drug dosages, fast and low-cost manufacturing are other advantages.

The literature purview incessantly reiterates the scope of 3DP technology in forcing a paradigm shift in medical practice during and after COVID-19 pandemic. The policy of self-reliance and integrated approach is key to tackle emergencies, which could be realized through 3DP. A 3DP in-house cell capable of working exclusively with clinicians, to design and develop novel, robust, and reliable technology could be employed for innovation. Further, hospital staff training and routine fabrication of hospital consumables should be encouraged so that during crucial time, technology could be utilized effectively and efficiently.

Conclusion

These above-mentioned applications are just the tip of the iceberg and demonstrates how 3DP could be valuable in affirming a sustainable system. We would like to emphasize that 3DP has tremendous potential in medical sciences. Though, the evidence of search data in the medical field is qualitatively and quantitatively insufficient. However, the incorporation of AM technology with medical sciences can make a difference in such emergencies. Any overnight change is hard to achieve, however, a strategically planned and fundamentally strong policy framework could reinforce the global healthcare system. Thus, this state-of-the-art and nimble technology is our glimmer of hope for our future sustainability.

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Declaration of Competing Interest

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.hlpt.2020.11.007.

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