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Chapter

3D Printing in Pharmaceutical Sector: An Overview

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Abstract

The pharmaceutical industry is moving ahead at a rapid pace. Modern technology has enabled the development of novel dosage forms for targeted therapy. However, the fabrication of novel dosage forms at industrial scale is limited and the industry still runs on conventional drug delivery systems, especially modified tablets. The introduction of 3D printing technology in the pharmaceutical industry has opened new horizons in the research and development of printed materials and devices. The main benefits of 3D printing technology lie in the production of small batches of medicines, each with tailored dosages, shapes, sizes, and release characteristics. The manufacture of medicines in this way may finally lead to the concept of personalized medicines becoming a reality. This chapter provides an overview of how 3D printed technology has extended from initial unit operations to developed final products.

Keywords: 3D print, personalized medicines, manufacturing, drug delivery

1. Introduction to 3D printing

Gaining immense interest both in academic and industrial sector is the concept of three dimensional (3D) printing (3DP) technologies. Domains like aerospace, engineering, FMCG, architecture, military, fashion industry, chemical industry, and medical field are by no way untouched by this technology [1, 2]. 3DP has a wide range of applications like tissue design, printing of organ, diagnostics, manufacture of biomedical devices, and the design of drug and delivery systems in the medical field [3, 4]. From the data originated by various techniques like computed tomography (CT) scan and magnetic resonance imaging (MRI), complex anatomical and medical structures according to the need of patient can be fabricated [5, 6]. Replacing and repairing the defective organs like kidney, heart etc. or all together creating a new organ that mimics the same functions as that of original are some additional uses of this technology [7]. This technology is so widespread that its applications include things that are an integral part of human life like clothing, eyeglasses, jewelry, parts of cars, and drugs that can be printed in almost any geometry and shape as per the requirement of the user [8].

In this technology a concept is transformed into prototype by taking help from 3D computer-aided design (CAD) files, hence digitally controlled and customized product can be fabricated [9]. This technology utilizes a bottom-up approach in which layers of materials like living cells, wood, alloy, thermoplastic, metals etc. are placed on top of each other in order to make the required 3D object [10]. Therefore, 3D printing is also known by other terminologies such as layered manufacturing, additive manufacturing, computer automated manufacturing, rapid prototyping, or solid freeform technology (SFF) [9].
fortunate people receive organs and the rest die due to donor shortage. Moreover, the procedures for organ transplants are so expensive that it is out of reach of common people. Another problem with transplant surgery is that donors with tissue match are difficult to find [7, 53].

The solution to this problem lies in the fact that the required tissue or organ should be fabricated using the patient’s own body cells, which would decrease the risk of tissue or organ rejection; moreover, the requirement for immunosuppressant will also be greatly reduced [7, 54].

In the conventional method of tissue engineering from a small tissue sample, stem cells are isolated, amalgamated with growth factor, and then multiplied in the laboratory. Then the cells are seeded onto scaffolds that direct cell proliferation and differentiation into a functioning tissue.

Placement of cell with accuracy, digitally controlled speed, drop volume, resolution, concentration of cells and diameter of printed cell are some of the additional advantages that 3D bioprinting offers over traditional tissue engineering [2, 54].

Depending upon the porosity, the type of tissue, and required strength, various materials are present to make the scaffolds. Among all materials, hydrogels are said to be the most suitable for building soft tissues [2, 55].

No doubt that organ printing is still in the phase of development but several researches have demonstrated its concept with proof. Scientists have built an artificial ear, cartilage and bone, and heart valve by the help of 3D printers [2, 47, 55]. Wang et al. used 3D bioprinting technology to deposit different cells within various biocompatible hydrogels to produce an artificial liver [54].

As with the increasing interest of researcher and academician and with vast potential of this technology it can possibly unfold new potential therapeutic drugs thereby greatly cutting research cost and time [7].

4.2 Unique dosage forms

Infinite dosage forms can be created using 3D printing. Inkjet-based 3D printing and inkjet powder-based 3D printing are the two main printing technologies
surrounded by barrier layers that modulate release, is found [55]. One example is the printing of a multilayered bone implant with a distinct drug release profile alternating between rifampicin and isoniazid in a pulse release mechanism. 3D printing has also been used to print antibiotic micropatterns on paper, which have been used as drug implants to eradicate *Staphylococcus epidermidis* [53].

In a research concerning drug release profiles, chlorpheniramine maleate was 3D printed onto a cellulose powder substrate in amounts as small as 10–12 moles to demonstrate that even a minute quantity of drug could be released at a specified time. This study displayed improved accuracy for the release of very small drug doses compared with conventionally manufactured medications [53].

5. Customized implants and prostheses

By the support of MRI, CT scan, and X-ray and its translation into .stl 3D print files, implants and prostheses of any possible shape can be made [1, 7, 55]. Standard as well as complex surgical implants and prosthetic limbs can be made as per need in time as less as 24 hours. Spinal dental and hip implants have been fabricated so far but their validation is a time-consuming process. Previously, in order to achieve a desired shape and size that fits perfectly, surgeons had to craft metal and plastic pieces and perform bone grafting or use drill machines to modify the implants [2, 7]. This also stands correct in neurosurgery cases due to the irregular shape of the skull whose standardization is a complex procedure.

Some examples of commercially and clinically successful 3D printed implants and prostheses are as follows:

a. First 3D printed titanium mandibular porsthesis was implanted successfully at BIOMED Research Institute in Belgium [1].

b. Dental, orthopedic, maxillofacial, and spinal implants are manufactured by a company named Layer Wise [55].

c. Invisalign braces is another successful commercial use of 3D printing.

By using silver nanoparticles, chondrocytes, and silicon, a prosthetic ear was made out of 3D printing technology that was able to detect electromagnetic frequencies. The impact of this technology is so extensive in the field of hearing aids that today 99% of customized hearing aids are made using 3D printers, because, as everyone’s ear canal has a different shape, this technology is able to provide perfect fit for each receiver and, moreover, the devices can be produced efficiently and cost effectively [7].

6. Anatomical models for surgical preparations

In order to have successful medical procedures, knowledge about patients’ specific anatomy before medical surgery is essential due to variations in individual and complex human anatomy. 3D printed models have helped extensively in this respect, making them a vital tool for surgical methods [1, 55].

One of the most complicated structures of human body is the head, whose 3D printed neuro-anatomical models are of great help to neurosurgeons. Sometimes, it is very difficult to gain detailed information about the connections between skull architecture, cerebral structure, cranial nerves, and vessels from radiographic 2D
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