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3D Printing Pharmaceuticals for Personalized Medicine

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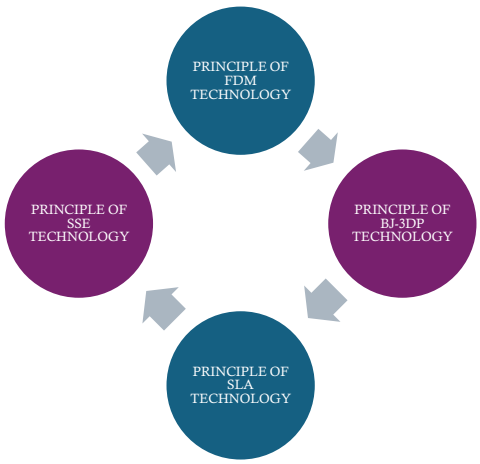
ABSTRACT

This review article aims to provide insights into 3D printing technology and its various applications in the pharmaceutical industry, including the creation of medical devices, personalized medications, multi-drug formulations, and more. It offers advantages like customization, improved pre-operative planning, and new drug delivery systems, but also faces challenges related to quality control and regulation, including material selection, process validation, sterilization, and scalability. In light of these advancements, regulatory bodies are updating their guidelines to maintain safety and efficacy. The article discusses several prevalent methods of 3D printing in pharmaceuticals and compares these with conventional manufacturing, highlighting the differences between the two approaches. It illustrates how 3D printing can benefit a range of patients, including children, the elderly, women, those with visual impairments, and individuals with chronic illnesses. Furthermore, the technology has multiple applications such as personalized medicines and dosage forms, microneedles, nanosuspensions, implants, polypills, complex oral solid dosage formulations, and even the digitization of pharmacies. Looking forward, the integration of artificial intelligence, nanotechnology, and Four-Dimensional (4D) printing may lead to more sophisticated medical devices and enhance disease management and outcomes. While 3D printing represents significant innovation in the pharmaceutical industry, concerns regarding scalability and regulatory issues persist. Nevertheless, this technology is poised to greatly influence healthcare delivery in the coming decades, along with shifts in global research and regulatory frameworks.

I. Introduction

3D printing is an additive manufacturing technique that builts object layer by layer using computer aided design (CAD). It is widely used in industry, light, automotive, construction, aerospace, Healthcare. It also used to produce tablets films, implants and patches.[1]

Principle of 3D printer



Principle of FDM technology

FDM technology is widely used in pharmaceuticals due to the advantages of simple equipment, low cost, and high product strength. Using computer-aided design software, 3D printed products are manufactured by deposiyting molten material layer by layer on printing platforms.[2]

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Principle of BJ-3DP technology

BJ-3DP is the primary 3D printing technology used for drug production. First, the roller spreads a thin powder layer on the platform, the droplets are sprayed through the removable printhead, and they selectively bind the powder together; then the platform is lowered, the roller spreads a new powder layer, the print head continues to add droplets, using the principle of layer-by-layer printing, and so on until complete; finally, the preparations are removed, the adhering powder is removed, and postprocessing is carried out.[3]

Principle of SSE technology

SSE is an additive manufacturing technology that deposits semisolid material layer by layer, where the extrusion head moves and extrudes the semisolid material in a set trajectory, stacking layers on top of each other until the product is printed. The technology is based on FDM, with the difference that the print material used in this technology is in a semisolid form at room temperature, so the temperature should be controlled when heating to avoid too much material softening due to high temperatures and not being able to retain its shape during deposition.[4]

Principle of SLA technology

SLA technology is based on the principle of photopolymerization and uses laser scanning to harden liquid resin to manufacture 3D-printed objects layer by layer. Depending on the printer setup, printing can be performed from the top down or the bottom up. When printing, the liquid tank is filled with liquid photopolymer resin, and the laser beam is focused on the resin surface by the scanning mirror, forming a light spot. The area swept by the light spot will be cured.

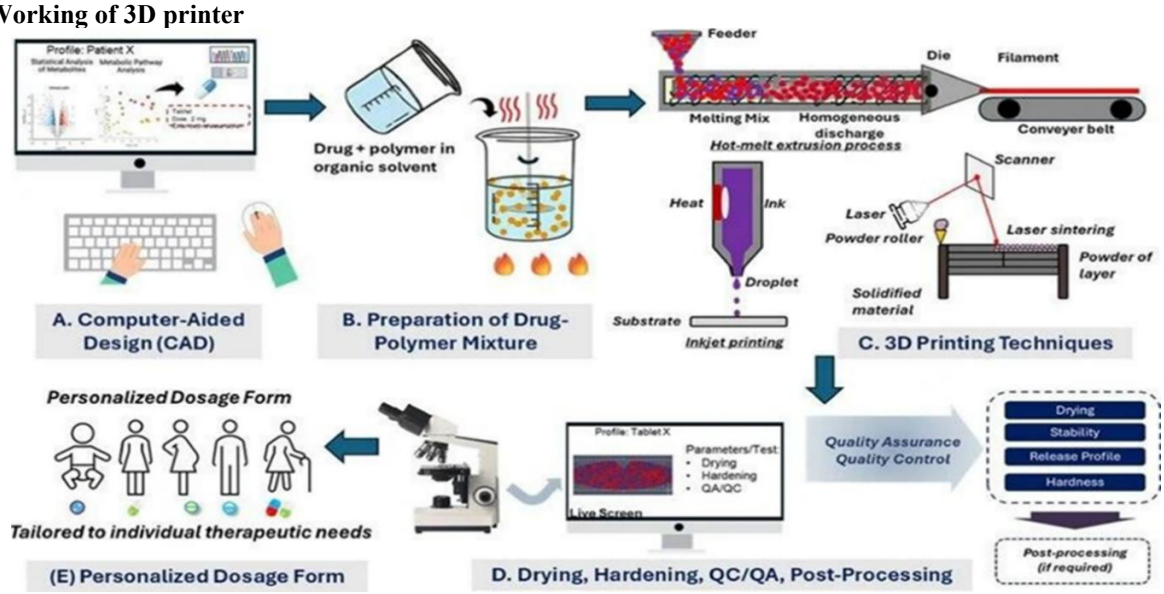
Advantage

- ✓ High production rates due to its fast operating systems.
- ✓ Narrow therapeutic window.
- ✓ High precision & accurate drug dosing.
- ✓ Less material waste → low cost.
- ✓ Personalized medicines possible.

Disadvantage

- ✓ Product liability.
- ✓ Fewer job opportunities.
- ✓ Requires precise ink/resin properties.
- ✓ Difficult for large structures.
- ✓ Limited compatible materials.
- ✓ Risk of misuse.[5]

Working of 3D printer



3D3D printer material

Polymers are key for medical 3D printing.Control drug release & stability.Both natural (gelatin, collagen) and synthetic polymers used.Synthetic polymers need cross-linking (may have risks). Natural polymers still important.

Types of Materials:

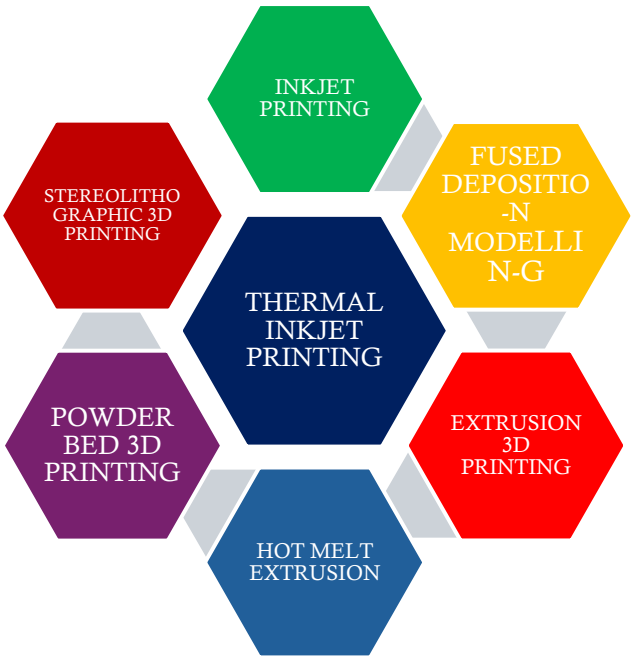
- ✓ High Impact Polystyrene (HIPS)
- ✓ Acrylonitrile Butadiene Styrene (ABS)

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[a] High Impact Polystyrene (HIPS) :
It is Used for support structures,Biodegradable & safe.It Used in packaging & medical trays and Reduces adhesion issues with heated bed.It Can be dissolved after printing.

[b] Acrylonitrile Butadiene Styrene:
It is widely used in 3D Printing due to Light weight, strong & durable.It Requires high temperature (210–250°C).[6]

Techniques in 3D printing



1.Thermal Inkjet Printing:
The basic idea behind thermal inkjet printing (TU) is that aqueous ink fluid is heated into vapor form, which then expands to force an ink drop out of a nozzle. The manufacture of drug-loaded biodegradable microspheres, drug-loaded liposomes, coating microelectrode arrays, and loading drug-eluting stents all involved the use of TIJ.

2.Inkjet Printing:
The creation of the desired structure largely relies on the movement of inkjet nozzles or the substrate, which leads to its classification as a "mask-less" or "tool-less" technique. This printing method enables high-resolution output as ink is deposited onto the substrate using either continuous inkjet printing (CU) or drop-on-demand printing (DOD). Inkjet printing offers several advantages, including low processing expenses, rapid production speeds, reduced waste, direct transmission of CAD information, and the ability to process materials over large areas with minimal contamination.

3.Fused Deposition Modeling (FDM):
The use of heat to soften or melt materials for object creation is a common technique in 3D printing. Fused Deposition Modeling (FDM) offers a range of dosage formulations, allowing for the production of customized medication doses and delayed-release prints without the need for external enteric coatings. However, FDM 3D printing has certain limitations, such as the limited availability of suitable polymers.

4.Extrusion 3D Printing:
In this method, material is directly extruded from an automated nozzle onto the substrate without the need for additional support material.A variety of materials— including molten polymers, pastes, semisolids, and suspensions—can be extruded. Extrusion is the most commonly utilized 3D printing technique, where materials are dispensed through robotically controlled nozzles. Unlike binder deposition, which requires a powder bed, extrusion methods can print on any surface.

5. Hot Melt Extrusion (HME):
Hot melt extrusion (HME) is a procedure that entails the continuous application of pressure to a device while simultaneously melting a polymer and a drug at elevated temperatures. This method incorporates stages of feeding, heating, blending, and shaping. In recent years, hot melt extrusion has proven effective in enhancing the solubility and bioavailability of moderately soluble pharmaceuticals.[7]

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6. Powder Bed 3D Printing:

This method employs powder jetting and a powder bed to apply thin layers of powder, with inkjet printers used to precisely drop liquid binders. In this two-dimensional (2D) process, the ink, which includes binders and active pharmaceutical ingredients (APIs) or binder solutions, is layered over the powder bed to form the final product gradually.

7.Stereolithographic 3D Printing

This method for producing 3D objects involves curing photosensitive materials through a process known as photopolymerization. SLA utilizes a digital mirroring device to direct a focused UV laser across the surface of a liquid photopolymer, working layer by layer. This process triggers a chemical reaction in the photopolymer, resulting in the gelation of the exposed areas. The full 3D object is built up by repeating this layer by-layer technique. Unreacted functional groups from the hardened first layer bond with the illuminated resin of the second layer, ensuring proper adhesion and completing the creation of each layer.[8]

Application of 3D printing technology

3D Printed Oral dispersible films :

3D Printed Oral dispersible films is a Thin polymer-based drug films.It Dissolve quickly in mouth.
and deliver the drug easily and quick and absorbed via oral mucosa or swallowed.

Medical Applications:

It is a medical device Started in early 2000s.It Used for dental implants & prosthetics (artificial device).[9]

Pharmaceutical application:

Pharmaceutical application is Rapidly growing field used in drug research and manufacturing.It have high reproducibility.

SL NO	DRUG	AUTHOR/YEAR	FORMULATION	PRINTING METHOD	REF NO
1	Rifampicin	Karanwad T et al. 2025	Implant	Powder bed inkjet printing	10
2	Acetaminophen	Chen M et al.2025	Capsule	Fused deposition modelling	10
3	Folic acid	Kefayat A et al,2025	Nanosuspension	Thermal inkjet printing	10
4	Nitrofurantoin	Sakthivel R et al.2023	Catheter	Fused deposition modelling	10
5	Fentanyl	Xu F et al.2025	Patches	Semi solid extrusion	11
6	Nitroglycerin	Wong WF et al.2023	Injection	Inkjet printing	12
7	Diclofenac	Iula G et al.2026	Patches	Selective laser sintering	12
8	Leuprolide	Eneko Larraneta Et al.2025	Tablet	Semi solid extrusion	13
9	Saline solution	Cunningham LO et al.2025	Microfluidic pump	Fused deposition modelling	14
10	Captopril	Kozakiewicz-Latala M et al.2026	Tablet	Selective laser sintering	15
11	Ropinirole HCL	Baran E et al,2024	Tablet	Fused deposition modelling	15
12	Mannitol	Ahmed Teama EM et al. 2025	Insulin	Inkjet printing	16
13	Dipyridamole	Wu Z et al .2025	Floating Tablet	Fused deposition modelling	16
14	Glipizide	Fang D et al.2021	Tablet	Selective laser Sintering	16
15	Nifedypine	Silva CF et al .2026	Multiactive tablets	Fused deposition modelling	16

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Risk assessment during 3D printing process

It is Important for quality control (appearance, uniformity, assay),and requires detailed analysis of workflow and variables.[17]

Future prospects

The growing demand for personalised and customised products particularly in the consumer goods industry,presents a significant opportunity for Indian 3D printing companies.[18]

Challenges

The cost of pre and post processing,and the limited selection of materials and technology limitations are the biggest 3d printing challenges.

Summary

It Enables patient-specific medicines (custom dose, shape, release profile),and Improves treatment effectiveness and compliance.

Conclusion

It Emerging transformative technology in pharmaceuticals and enables personalized, patient-specific medicines supports advanced and flexible drug delivery systems.It Allows customized and novel dosage forms.

REFERENCE

[1]. Hemanth K., Hemamanjushree S., Abhinaya N, et al. A comprehensive review of 3D printing technology, its role in new dosage forms, and regulatory aspects. Research Journal of Pharmacy and Technology, 2021; 14: 562-72.

[2]. An overview of 3D Printing. Mr. Guruprasad Kantilal Dherel et al. ISSN: 2320-2882, page no: 620-621.

[3]. Yingya Wang,Natalja Genina,Anette Mullertz Basic & Clinical Toxicology 134 (3),325-332,2024.

[4]. Weining Sun ,Jukka Rantanen ,Natalja Genina Journal of Pharmaceutical Sciences 113(9),2957-2966,2024.

[5]. Prashanth Ravi ,Parimal Patel Additive Manufacturing in Pharmaceuticals,97-123,2023.

[6]. Satyajit Sahoo, Sohan Patel, Tejas Patel et al. A review of 3D printing technology in pharmaceutical sector. International journal of novel research and development, Volume 9, Issue 6 June 2024, ISSN: 2456-4184.

[7]. Abdul W Basit ,Sarah J Trenfield Pharmaceutical Journal 308 (7959),2022.

[8]. Advancements in 3D printing materials ,Haridas, Maher Ali Rusho, N Rajeswari, A John Rajan, Avvaru Praveen Kumar,Applied Chemical Engineering 7 (2), ACE-3867, 2024.

[9]. Gabriel Gaala, Melissa Mendesa, Tiago P. de Almeida, "Simplified fabrication of integrated microfluidic devices using fused deposition modelling 3D printing" Science Direct.

[10]. Advancements and limitations in 3D printing materials and technologies: a critical review Syed Fouzan Iftekar, Abdul Aabid, Adibah Amir, Muneer Baig Polymers 15 (11), 2519, 2023.

[11]. Thermal inkjet printing: prospects and applications in the development of medicine Md Jasim Uddin, Jasmin Hassan, Dennis Douroumis Technologies 10 (5), 108, 2022.

[12]. Inkjet printing of pharmaceuticals Paola Carou-Senra, Lucia Rodríguez-Pombo, Atheer Awad, Abdul W Basit, Carmen Alvarez-Lorenzo, Alvaro Goyanes Advanced Materials 36 (11), 2309164, 2024.

[13]. Harshit K Dave ,Sandip T Patel Fused deposition modelling 3D printing,1-21,2021.

[14]. Optimising 3D printed medications for rare diseases: In-line mass uniformity testing in direct powder extrusion 3D printing Carmen Alvarez-Lorenzo, Alvaro Goyanes International Journal of Pharmaceutics 668, 124964, 2025.

[15]. Dumpa N, Butreddy A, Wang H, Komanduri N, Bandari S, Repka MA. "3D printing in personalized drug delivery: An overview of hot-melt extrusion-based fused deposition modeling." International Journal 10.1016/j.ijpharm.2021.120501.

[16]. van den Heuvel, K.A.; de Wit, M.T; Dickhoff, B.H. Evaluation of lactose based 3D powder bed printed pharmaceutical drug product tablets. Powder Technol. 2021, 390, 97–102.

[17]. Systematic screening of photopolymer resins for stereolithography (SLA) 3D printing of solid oral dosage forms: Investigation of formulation factors on printability outcomes Carlo Curti, Daniel J Kirby, Craig A Russell International Journal of Pharmaceutics 653, 123862, 2024.

[18]. Venkataramana Gadi1, Jyothsna M1, Bhavani B– "A Comprehensive Review of 3D Printing Applications in Drug Development and Delivery". Journal Of Pharma Insights And Research.2024, vol 02(04),page no:139-145.