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Review Article

3D Printing in Pharmaceutical Technologies : A Review

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ABSTRACT

Personalized medicine and medication research are being revolutionized by 3D printing in pharmaceutical technology. 3D printing makes it possible to precisely fabricate intricate medication delivery systems, resulting in personalized dose forms that are suited to the requirements of each patient. This technique makes it easier to quickly prototype novel medications, create controlled release formulations, and create multi-layered tablets. It lowers expenses, improves manufacturing efficiency, and has the potential to improve treatment results through patient-specific medicines.

INTRODUCTION

The unmatched technique of three-dimensional printing stacks materials onto a substrate using computer-aided drawing tools and programming to produce three-dimensional objects. All phases of the medication development process, including preclinical research, clinical trials, and primary healthcare, may now be completed using 3D printing. Through the use of three-dimensional (3D) printing, a variety of drug delivery systems have been created, such as oral controlled release systems, micropills, microchips, drug implants, quick-dissolving tablets, and multiphase release dosage forms. Active pharmaceutical ingredients (APIs) are precisely deposited layer by layer utilizing computer-aided design (CAD) models.3D printing offers immense possibilities for personalized medicine, complicated prescription formulations, and tailored doses. The pharmaceutical manufacturing process has long employed mass production techniques, which has resulted in a restricted number of dosage forms and delayed medicine delivery. However, a revolutionary invention known as 3D printing has emerged as a force that may overcome these limitations. Additionally, complex medication formulations that were previously challenging to

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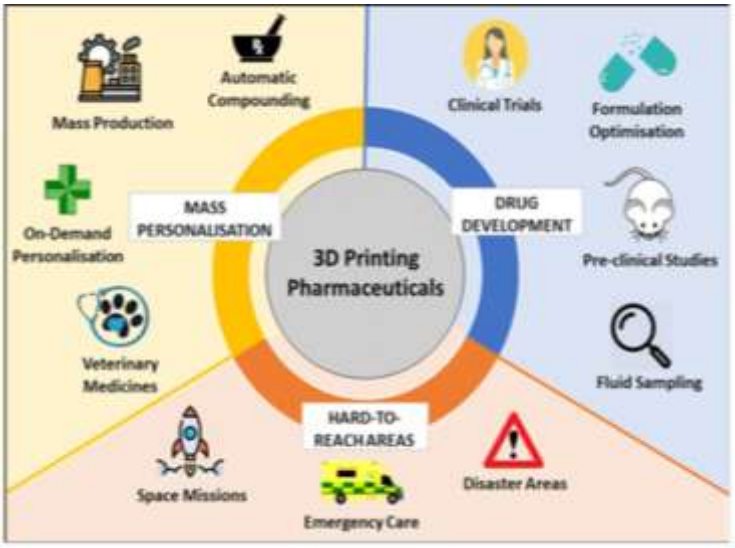
create using conventional techniques are now easy to prepare.



HISTORY OF 3D PRINTING

Pierre A. L. Giraud first proposed the idea of 3D printing, or 3D printing, in the early 1970s. He explained how powdered material was applied and how a high-intensity beam was used to solidify each layer. It is possible that in this case, the item may be prepared by melting materials like metal or plastic. Ross In a submitted patent, Householder described the idea of binding sand with various materials in the early 1980s under the title " A molding method for building layers of a three-dimensional object" and Carl Deckard developed a method called selective laser sintering (SLS) that uses laser beams to harden powdered beds. Chuck Hull created the first method that he sold, stereolithography(SLA). This technique was based on the photopolymerization of liquid resin by ultraviolet light. In the late 1980s, Scott Crump submitted a patent application for fused deposition modeling (FDM), a technique that used thermoplastic material to prepare objects. In the 1990s, MIT scientist Emanuel Sachs created "three-dimensional printing techniques" by fusing certain powder areas with a binding agent.

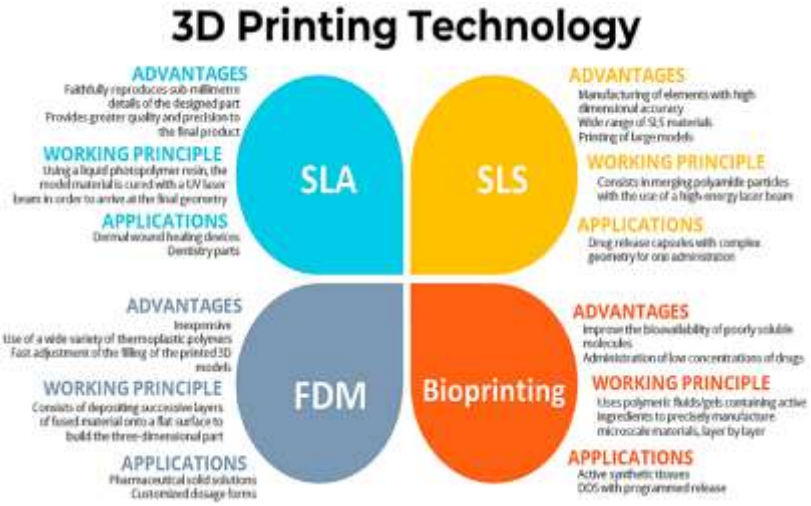
Advantages of 3D Printed Drug Delivery

- Superior medication loading capacity in contrast to traditional dose formulations.
- Precise and accurate dosage of strong medications that are given in little amounts to have desired effects.
- Lower manufacturing costs as a result of less material waste.
- Appropriate drug delivery for active substances that are challenging to manufacture, such as those with limited therapeutic windows and poor water solubility.
- Depending on a patient's environment, age, gender, genetic variations, and ethnicity, their medicine can be tailored for them.
- Treatment can be customized to improve patient compliance in cases of multi-drug therapy with several dosing schedules.

Disadvantages of 3D Printed Drug Delivery

- A significant obstacle is nozzle-related issues, such as print head halting, which alters the final products structure.

- The blockage in powder printing is an additional challenge.
- Potential to alter the finished structure in response to changes in storage conditions, mechanical stress, and the impacts of ink formulations.
- Features of printers and how they affect printing costs and quality.

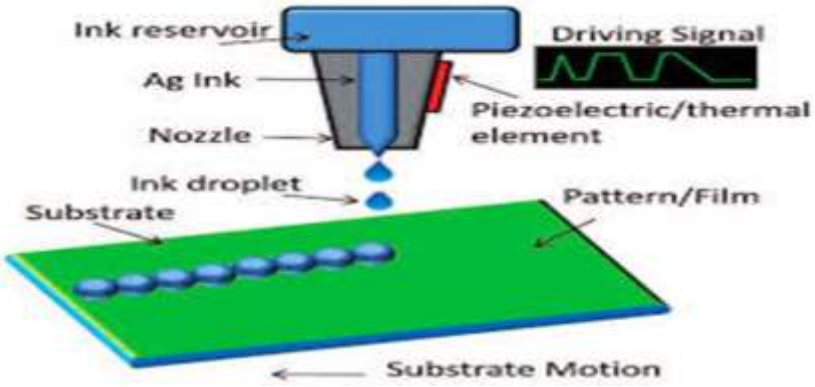


METHODS FOR 3D PRINTING

Using digitally designed layer-by-layer material deposition to create free-form designs, 3D printing provides a vast array of intricate production procedures.

Thermal Ink-Jet Printing

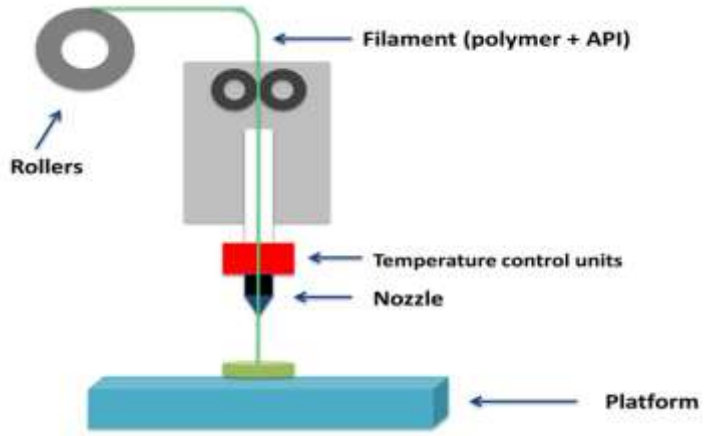
Heat is used in thermal inkjet printing to turn the aqueous ink solution into a vapor, which then expands to force the ink drop out of a nozzle. Drug-eluting stents, coating patterns for microelectrode arrays, drug-loaded liposomes, and drug-loaded biodegradable microspheres are among its applications. Additionally, it is a practical and efficient way to create biologic films without compromising protein function.



Fused deposition modeling (FDM)

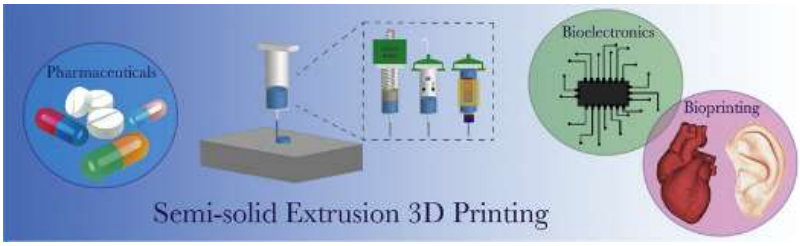
One of the most widely used 3D printing methods is fused deposition modeling (FDM), where things are created by melting or softening materials with heat. Personalized medication dosages and delayed release printlets are enabled by fused deposition modeling 3D printing without the need for an external enteric coating. The system's shortcomings are indicated by this 3D printing,

including the absence of appropriate polymers, sluggish and frequently insufficient drug release due to the drug's retention in the polymers, as well as the underestimation of the drug's and additives' compatibility.



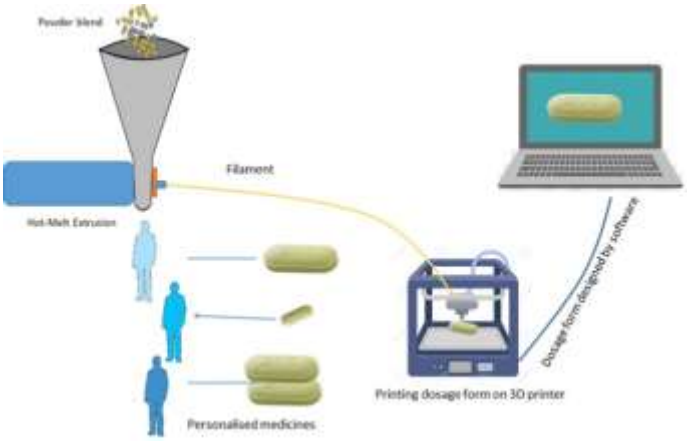
Extrusion-3D Printing

With this method, no extra support material is required because the material is extruded onto the substrate from the automated nozzle. It is solely used to make expectorating tablets that include guaifenesin. Components that can be extruded include pastes, suspensions, semisolids, and molten polymers.



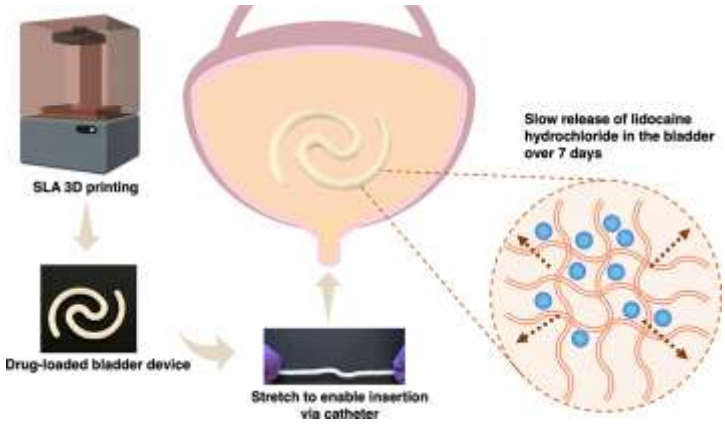
Hot melt-extrusion (HME)

Melting medications and polymers at high temperatures while exerting pressure in a sequential manner within an instrument is known as hot melt extrusion (HME), and it is used for mixing. This manufacturing process is continuous and includes feeding, heating, mixing, and shaping. It has been demonstrated in recent years that hot melt extrusion can maximize the bioavailability and solubility of medications that are only moderately soluble.



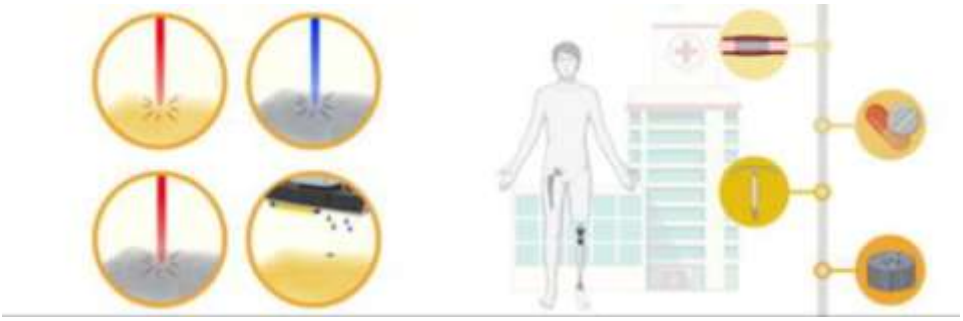
Stereolithography

Stereolithography creates three-dimensional structures by using a computer-controlled laser beam to solidify liquid polymers or resin. Compared to earlier forms of other 3DP among the many advantages of stereolithography are its exceptional resolution and ability to avoid heat processes that might be harmful to certain medication ingredients.



Powder Based-3D Printing

Using inkjet printers and powder jetting or powder beds, this method produces thin powder layers by instantaneously spraying liquid binder droplets. The ink (binders, APIs, or binder solutions) is sprayed over a powder bed using a two-dimensional (2D) process to produce the finished product layer by layer. Since powder and binder solutions are widely utilized in the pharmaceutical sector Comparing this approach to other options, it is simpler to modify for pharmaceutical manufacturing.This method's drawbacks include the need for further drying to remove solvent residues, the accumulation of extra powder during printing that leads to waste, and the potential for low mechanical strength in the drug delivery system because of the powder's porous design.



RISK EXAMINATION IN THE 3D PRINTING PROCEDURE

Determining the level of risk is a crucial step in 3D printing technology. It was primarily carried out to avoid failure of quality assurance parameters including assay, consistency of content, appearance, etc. In order to maintain the quality of the products produced in industries, risk factors are recognized with the process and process variables.

The Risk factors that are checked in these conditions are

- If a certain design cannot be printed by a given printer, software controls should be used.
- Layer thickness monitoring in real time is necessary to manage layer thickness variations.
- Controlling the manufacturing location's temperature and moisture content led to incorrect layering, mostly as a result of shifting climatic circumstances.
- It may be possible to prevent incorrect positioning in the printer by monitoring the print head's height and speed during printing.
- Monitoring the powder's water content and molecular size dispersion will help prevent uneven layers.
- Inconsistent agglomeration results from variations in binder surface tension or viscosity.

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