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Novel of 3D Printing Technology: Review

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ABSTRACT

New possibilities in 3D printing may open up a whole new chapter of opportunities for pharmaceutical research and bio-technology applications. There are a number of ways that could be used as drug dosage forms, supporting delivery, or helping to research cures. To explore its work. 3D printing has been around for many years; predominantly been used in manufacturing. This type of printing, also called stereo-lithography, can create almost any object by fusing different materials, layer by layer, to form a physical version of a digital 3D image. Over the past 15 years, 3D printing has expanded into the healthcare industry, where it has used to create custom prosthetics and dental implants. Now, there may be a chance to use it for personalized healthcare.

Since a three-dimensional (3D) printed drug was first approved by Food and Drug Administration in 2015, there has been a growing interest in 3D printing for drug manufacturing. There are multiple 3D printing methods – including selective laser sintering, binder deposition, stereo-lithography, inkjet printing, extrusion-based printing, and fused deposition modeling – which are compatible with printing drug products, in addition to both polymer filaments and hydrogels as materials for drug carriers. We see the adaptability of 3D printing as a revolutionary force in the pharmaceutical industry. Release characteristics of drugs may be controlled by complex 3D printed geometries and architectures. Precise and unique doses can be engineered and fabricated *via* 3D printing according to individual prescriptions. On-demand printing of drug products can be implemented for drugs with limited shelf life or for patient-specific medications, offering an alternative to traditional compounding pharmacies. For these reasons, 3D printing for drug manufacturing is the future of pharmaceuticals, making personalized medicine possible while also transforming pharmacies.

Keywords: 3D Printing, Pharmaceuticals Manufacturing.

1. Introduction

The research and development of pharmaceuticals could be dramatically improved by 3D printing. Instead of printing objects made of plastics or metals, imagine printing pills or human organs and tissue. This would make it easier for companies to test drugs more safely (and cheaper). It appears to be within the reach of science- and closer than ever before [1]. Horizon changes in health care compared to other sectors, 3D printing technology has played a minor role in health care. Experts estimate that health care accounts foronly1.6% of all investments in the $700 billion 3D printing industry. However, the number is expected to rise to 21% in the next 10 years. The latest research shows that health and medicine have under gone even more drastic development. According to market research company Markets and Markets.com, 3D printing for medical applications can reach $2.13 billion in market value by 2020. Applications such as dental implants are already very commercially successful, it is expected that around 50,000 custom-made Envisaging braces are printed every day .Here are four other ways 3D printing which can change the world of pharmaceuticals forever [2].

1.1. Personalized drug dosing

3D printing can give personalized medicine a new dimension. Experts and researchers think in a simpler form of producing personal 3D printed oral tablets. Medical writer C. Lee Ventola conducted extensive research on this topic for her book Medical Applications for 3D Printing: Current and Expired Uses. She writes that personalized 3D-printed drugs can be especially beneficial for patients who react differently to the same drug. In addition, doctors or pharmacists can use individual information from each patient, such as age, race, and gender, to design the optimal dose of a drug, rather than relying on a standard dose.3D printing also allows you to print pills in a complex layer construction, using a combination of drugs to treat multiple diseases at the same time. The idea is to give patients a single pill to treat everything they need [3].

1.2. Unique dosage forms

3D printing can also be used to create unique dosage forms in pharmaceutical production processes. The goal is to create endless dose forms using inkjet-based 3D printing technology. According to experts, this is likely to challenge the manufacturing of conventional drugs. Many drugs have already benefited from the process of creating new dosage forms, and more innovation is expected as time passes.

1.3. More complex drug release profiles

The drug release profile describes how drugs decompose when taken by patients. The first-hand design and printing of drugs makes it easier to understand their release profiles. 3D printing can print personalized drugs that promote the release of targeted and controlled drugs by printing a binder on a matrix powder floor. This creates barriers between active ingredients, allowing researchers to study variations in release more closely. In the coming years, researchers and investment will likely increase as pharmaceutical manufacturers begin to understand the full range of opportunities that enable them to produce more effective drugs [4].

1.4. Printing living tissue

Although it is unlikely that this will be fully possible on a large scale in the future, experts predict that science is less than 20 years from fully functioning 3D printed hearts. However, 3D is still challenging due to the complexity of the vascular network. According to Tony Atala, Director of the Wake Forest Regenerative Medicine Institute, each organ has different levels of complexity. Therefore, while some tissues are easier to print, such as flat structures such as human skin, the most difficult areas of organ printing are heart, liver and kidneys [3, 4].

1.5. How It Works.

Different types of 3D printers use different technologies to process different materials. It is important to understand that one of the most fundamental limitations of 3D printing – material and application – is that there is no "one solution fits all”. For example, some 3D printer's process powder materials (nylon, plastics, ceramics, and metals) and use light/heat sources to fuse, melt, and fuse powder layers into defined shapes. Others treat polymer resin materials and again use light/laser to bind the resin into ultra-thin layers. The filtration of fine drops is another 3D printing process, similar to the 2D inkjet printing, but with higher ink materials and binders to fix layers. It is possible that the most common and easily recognized process is deposit, a process used by most entry-level 3D printers.

This process extrudes plastics, usually PLA or A. B. S, start with 3D C. A. D files create 3D models or create predetermined shapes by scanning the filament layer with a heated extruder, or by creatinga3D model with a 3D scanner. Because the part can be printed directly, it is possible to make very detailed and complex objects, often equipped with built-in functionality, which eliminates the need for assembly! Another important point to be emphasized, however, is thatno3D printing process currently offers plug-and-play options. There are many steps before printing, and more steps when apart leaves the printer. In addition to the difficult design realities of 3D printing, file preparation and conversion can also be costly and complex, especially when the component requires complex support during the build process. However, the software updates and updates these 9 layers each layer so that the printer creates pre-defined shape functions are ongoing and the situation is improving. In addition, once the printer is finished, many parts will have to be finished. Support removal is obvious in processes requiring support, but there are other traditional finishing methods, such as sanding, lacquer, paint, and other finishes. All of this is usually done manually, requiring skill and/or time and patience. [5,6]

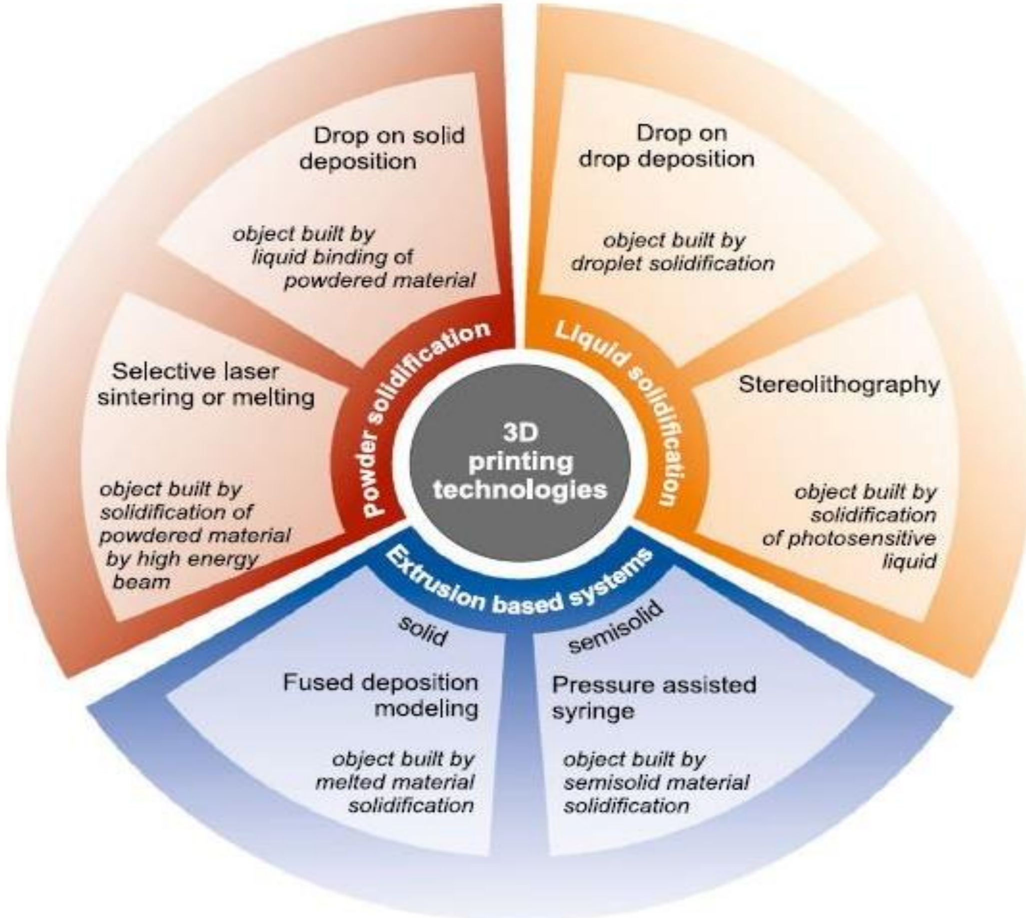

Figure 1: Schematic view of 3DP methods applied for drug formulate

1.6. 3D Printing - Harnessing the power of 3DP to develop innovative medicines.

Powder liquid 3Dprinting technology (P3D printing) was developed as a rapid prototyping technology at the Massachusetts Institute of Technology (MIT) in the late1980s.This technology uses water liquids to bond multiple powder layers to create a wide range of products using unique patent-protected processes. From 1993 to 2003, research was extended to tissue engineering and pharmaceutical use. For years, this process and associated layered manufacturing techniques have been used to foster innovation and progress in various industries. From the manufacture of automobile parts to the manufacture of complex biological structures, this process has proved invaluable with huge untapped potential. Pharmaceutical rights for MIT's 3DP process are licensed exclusively to Aprecia. Aprecia sees the opportunity to improve the patient's experience with medications and applies advanced 3DPtechnology in the field of pharmaceuticals [7].

2. 3D Printing Technology

3D printing is an additive manufacturing technology used to create three-dimensional objects by laying successive layers of material. Rapid proto-typing is a mechanical method for quickly generating 3D objects on computers linked to computers with reasonable dimensions. Custom3D printing concepts are exciting to almost everyone. This revolutionary method to create a3Dmodel using inkjet technology eliminates the need to design, print, and glue separate models, and saves time and costs. Now you can create complete models with 3D printing in a single process. The basic principles are material cartridges, output flexibility and the conversion of code into visible patterns [8].

2.1. General explanation of 3D Printing

A method of manufacturing known as 'Additive manufacturing', due to the fact that instead of removing material to create a part, the process adds material in successive patterns to create the desired shape.

Main areas of use:

- Prototyping
- Specialized parts – aerospace, military, biomedical engineering, dental
- Hobbies and home use
- Future applications– medical (body parts), buildings and cars

3D printing uses software to cut 3D models into layers (most of them are 0.01 mm thick). Each layer is traced on the printer's build plate, and when the pattern is completed, the build plate is reduced and the next layer is added to the previous layer. Typical manufacturing technology is known as subtractive manufacturing because the process is to remove materials from a prefabricated block. Processes such as milling and cutting are sub-productive manufacturing techniques. Because this type of processing creates a lot of waste, the cut material can usually be used for other purposes and is simply sent as waste. 3D printing eliminates this waste, since the material is placed only where needed, the rest is left as an empty space. [9,10]

2.2. Bringing ZipDose® Technology to life

Aprecia has developed ZipDose® platforms to rapidly dismantle high-dose drugs using its proprietary 3DP manufacturing process. ZipDose® technology produces products layer by layer without compression, punches or dies. First, the powder mixture is deposited in a single layer. Then the water binding liquid is applied, the powder and liquid interactions are applied and the material is glued together. 12 This process is repeated several times to produce a solid but very porous formulation, even at high dose loading. Aprecia's ZipDose® products are designed for:

- Rapidly disintegrate on contact with liquid by breaking the bonds created during the 3DP process
- Support dose loading up to 1,000 mg
- Allow the application of enhanced taste-masking techniques [8].

2.3. Advantages and Limitations:

Layer-by-layer production allows for more flexibility and creativity in the design process. Designers no longer have to design for manufacturing, but can create lighter and stronger parts by better design. Parts can be completely redesigned to make them stronger and overall lighter in the places they need [11]. 3D printing significantly speeds up the design and prototyping process. There is no problem of creating one part at a time and changing the design every time it is produced. You can create parts within hours. Reduce the design cycle to a few days or weeks rather than months. Due to the decline in the price of 3Dprinters, some 3D printers are now available to ordinary consumers and small businesses. In general, the limitations of 3D printing include expensive hardware and materials. This leads to expensive parts and makes it difficult to compete with mass production. It also requires CAD designers to create the customer's requirements and costs can be high if the part is very complicated. 3D printing is not the answer to all kinds of production methods, but its progress has helped accelerate design and engineering more than ever. By using 3D printers, designers can create unique artworks, complex buildings and product designs, as well as produce parts in space. The impact of 3D printing on many industries is obvious. There are articles saying that 3D printing will lead to the next industrial revolution by bringing the means of production back to the reach of designers and consumers [12].

3. Applicable 3D Printing Methods

For the printing of drug products, we use the3D printing technology, which incorporates biocompatible materials and pharmaceutical components. Many 3D printing methods have been reported to be adapted to the needs of bio-printing and pharmaceutical manufacturing; (A) Selective laser sintering: Lasers sinter the powder bed by recharging it with a roller system; lasers sinter the powder to form the desired print. (B) Binder deposit: A binder solution is found on the powder bed, which is refilled with a roller system; at contact, the binder dissolves the powder and re-crystalizes it. (C) Stereolithography: Lasers are directed to reverse printing beds in the ink pool and the ink is cured and consolidated by the laser. (D) Inkjet printing: On the left, the thermal inkjet nozzle creates bubbles with heating elements to generate droplets in continuous ink flow. On the right, the piezoelectric element creates an acoustic wave using electrical pulses and forms an air bubble, thereby producing drops. (E) Extrusion-based printing (Viscosity Materials): On the left, the piston is used to apply mechanical pressure to the ink to extrude continuous streams. On the right side, you apply the above-mentioned pneumatic pressure to extrude the ink. (F)Solid Material Deposit Modeling: Solid filament is fed into the nozzle by a rolling device, then melted by a heating element in the nozzle and extretched onto the printed bed. [13.14].

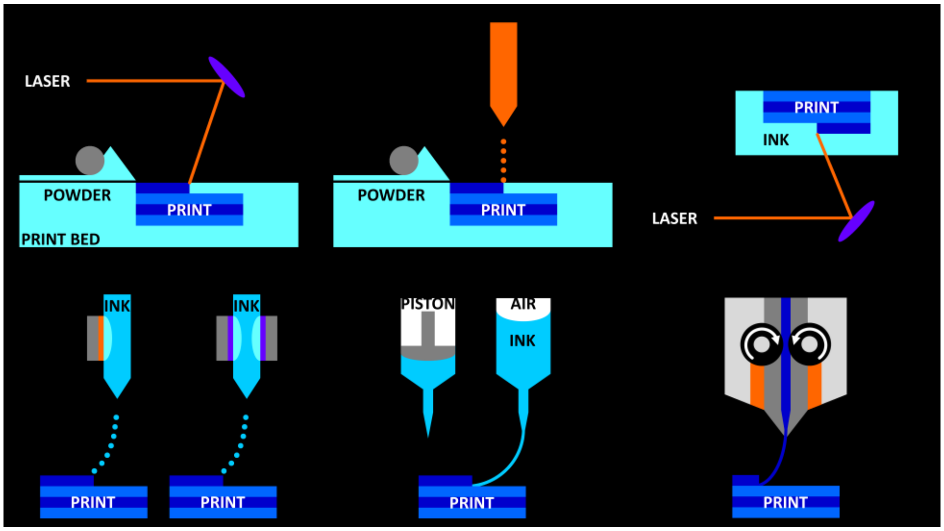

Figure 2: 3D printing methods for drug manufacturing.

4. Types of 3D Printing

4.1. FDM – Fused Deposition Modeling

This is an additive manufacturing technology commonly used for modeling, prototyping and manufacturing applications. FDM is based on the principle of additive" by laying the material in layers. A plastic film or metal wire is pulled out of a coil and supplies material to an extruder nozzle that can activate or deactivate the flow. The nozzle is heated to melt the material, and can move horizontally and vertically with a numerical control mechanism, and is controlled directly by a computer-assisted manufacturing software package (CAM). Models and parts are formed by extruding small beads of thermoplastic materials into layers, and the materials are hardened immediately after extruding from the nozzle. A stepper motor or servomotor is usually used to move the extrusion head. FDM is an important form of rapid prototyping that is used for rapid prototyping and manufacturing. Rapid prototyping allows iterative testing and rapid production is a relatively inexpensive alternative for very short runs.

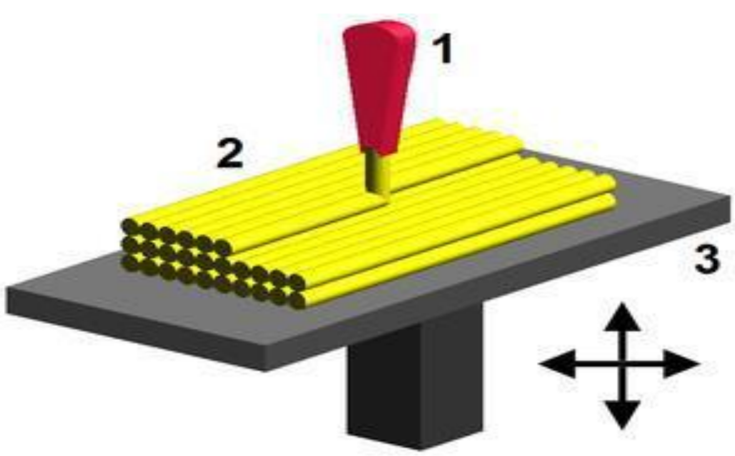

Figure 3: Fused Deposition Modeling

Advantages: Cheaper since uses plastic, more expensive models use a different (water soluble) material to remove supports completely. Even cheap 3D printers have enough resolution for many applications.

Disadvantages: Supports leave marks that require removing and sanding. Warping, limited testing allowed due to Thermo plastic material. [15, 16].

4.2. SLA – Stereo-lithography

Stereo-lithography is a process of additive manufacturing that uses a barrel of a liquid ultraviolet-coated photopolymer resin and an ultraviolet laser to build parts layers one by one. The laser beam traces the cross sections of the surface of the liquid resin for each layer. Exposure to ultraviolet laser light heals and binds the patterns traced on the resin to the below layer. After mapping the pattern, the SLA elevator platform falls at a distance equal to the thickness of a single layer, typically 0.05 to 0.15 mm (0.002to0.006 inches). Then there sin-filled blade passes through the cross section of the part and re-coated the parts with new material. In this new liquid surface, the pattern of the next layer is followed and joined to the previous layer. This process produces acomplete3D part. After construction, the parts are immersed in a chemical bath to clean the excess resin and then treated in ultraviolet ovens.

Stereo-lithography necessitates the utilization of supportive structures that function to affix the component to the elevator platform, avert deflection caused by gravitational force, and secure the cross sections in their designated positions, thereby enabling them to withstand lateral pressure exerted by the re-coater blade. The creation of these supports occurs automatically during the preparation of 3D Computer-Aided Design models for implementation on the stereo-lithography machine, although they may also be manually adjusted. Unlike in other, more economical, rapid prototyping technologies, the extraction of the supports from the final product is a manual process. [17].

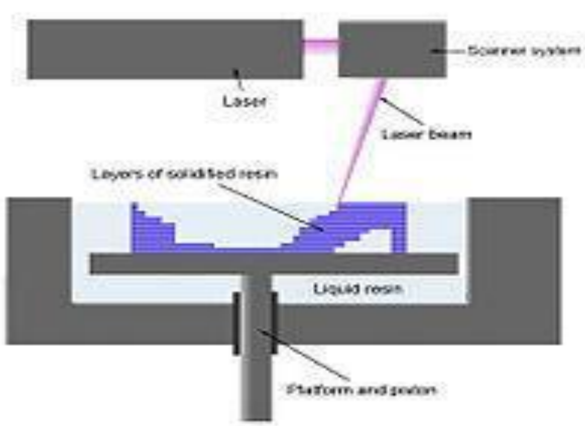

Figure 4: Stereo-lithography

Advantages and Disadvantages

Stereo-lithography has the speed advantage; working parts can be produced in a single day. Depending on the size and complexity of the project, the time it takes to produce a single part can range from several hours to over a day. The majority of stereo-lithography machines have a maximum part size of about 50x50x60 cm (20"×20"×24"). However, some machines, like the Mammoth machine, have a build platform measuring 210x70x80 cm, which allows it to produce single pieces longer than two meters. Stereo-lithography-produced prototypes can be used as master patterns for injection molding, thermoforming, blow molding, and other metal casting operations because they are robust enough to be machined. Stereo-lithography has historically been costly, despite its ability to create a vast array of shapes. The price of a liter of photo-curable resin has historically varied from $80 to $210, and the cost of a stereo-lithography machine can range from $100,000 to over $500,000. Recently, more affordable SLA 3D printers have been developed, and it is reasonable to believe that more will be produced in the future that are accessible to the majority of people. [17].

4.3. SLS - Selective laser sintering

This method of additive manufacturing fuses tiny powders of plastic, metal (direct metal laser sintering), ceramic, or glass into a mass with the required three-dimensional shape using a high power laser, such as a carbon dioxide laser. By scanning cross-sections created from a 3-D digital description of the part (for instance, from a CAD file or scan data) on the surface of a powder bed, the laser selectively fuses powdered material. The powder bed is lowered by one layer thickness after each cross-section scan, a fresh layer of material is applied on top, and the process is repeated until the part is finished [18]. An SLS machine usually uses a pulsed laser because finished part density is dependent on peak laser power rather than laser duration. In order to facilitate the laser's ability to raise the temperature of the chosen regions all the way to the melting point, the SLS machine preheats the bulk powder material in the powder bed to a temperature slightly below its melting point. Single-component powder is used by certain SLS machines, like in direct metal laser sintering. But the majority of SLS devices employ two-component powders, usually a combination of powders or coated powder. When working with single-component powders, the laser only melts the particle's outer layer (surface melting), joining the solid, non-melted cores to the preceding layer and to each other [19].

SLS can create parts from a comparatively large variety of powder materials that are readily available in the market when compared to other additive manufacturing techniques. These include metals like titanium and steel, alloy mixtures, composites, green sand, and polymers like nylon (neat, glass-filled, or with other fillers) or polystyrene. Liquid-phase sintering, partial melting, and full melting are the possible physical processes. It is possible to achieve up to 100% density with material properties that are similar to those from traditional manufacturing techniques, depending on the material. Often, a powder bed can accommodate a large number of parts, allowing for extremely high productivity. SLS systems are the machines that carry out SLS. Because SLS technology can easily create extremely complex geometries directly from digital CAD data, it is widely used worldwide. Although it was first used to construct prototype parts early in the design cycle, limited-run manufacturing is starting to use it more and more to create end-use parts. Art is one less common but quickly expanding application of SLS [20].

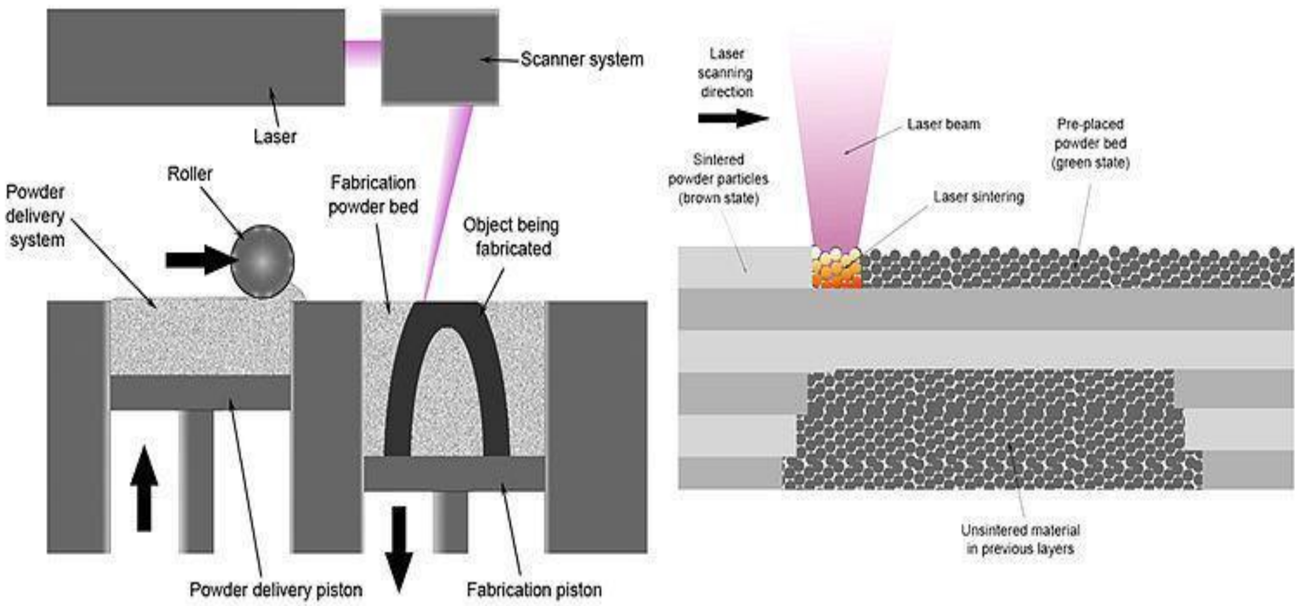

Figure 5: Selective laser sintering

Benefits

Compared to conventional manufacturing methods, SLS offers numerous advantages. Since no specialized tools are needed and parts can be assembled in a few hours, speed is the most obvious benefit. SLS also makes it possible to test prototypes more thoroughly. Prototypes now consist of working hardware constructed from the same material as production components since SLS is capable of using the majority of alloys. Moreover, SLS is among the few industrially employed additive manufacturing technologies. As the parts are assembled layer by layer, internal features and passageways that would be impossible to cast or otherwise machined can be designed. Simpler, more economical assemblies can be created by reducing complex geometries and multi-component assemblies to fewer parts. Short production runs can benefit from SLS since it doesn't require specialized tooling like castings [21].

Applications

Using this technology, direct parts are produced for a range of industries, such as the tooling industry, which produces direct tooling inserts, and the aerospace, dental, medical, and other industries that have small to medium-sized, highly complex parts. Having the capacity to "grow" multiple parts at once and a build envelope of 250 x 250 x 185 mm, SLS is an incredibly efficient technology in terms of both time and money. The technology reduces the time needed to develop new products through rapid prototyping, and it is also used in production manufacturing as an economical way to simplify complex geometries and assemblies [22].

In addition to a plethora of non-healthcare applications, 3D printing is being researched and used for implantable drug delivery devices, food products, prosthetics, tissue bio printing, and oral medications. It was found that 3DP can produce more complex products at a reasonable cost, on demand, and/or with patient customization when compared to traditional drug manufacturing. Current technologies restrict the forms and internal structures of drug products. These properties can be as complex as one could want when employing additive manufacturing, which may be helpful in the case of several drug release profiles integrated into a single dosage form [23–24]. [25].

A few objectives include minimizing side effects, printing toroidal, cylindrical, or perforated oral formulations, or employing diffusion-controlling excipients with radial gradients of erosion to achieve nearly zero-order release. The FDA reports that the demand for personalised medicine is rising and is becoming a megatrend. As a result, one significant benefit of 3DP medicines may be their capacity to produce unique, individual, or multi-drug and/or multi-dose formulations. Research in this area began in the early 1990s, but since 2015, the FDA has only approved one 3D printed or dispersible drug (Spritam®), despite their continued active involvement in the development of 3DP for pharmaceutical applications [26–27].

Although official guidelines for 3D printed drugs are still a ways off, the Agency is actively researching 3D printing and published a set of guidelines for 3D printed medical devices at the end of 2017. Spritam® tablets are made without compression using a binder jetting method (Zipdose® technology). This method was not developed for individual dosing, but it did solve a significant problem: levetiracetam dosages up to 1000 mg were needed, but the traditional compressed tablet's size prevented epileptic patients from ingesting it. Spritam®'s 3D manufacturing process significantly reduced the amount of excipients in the finished product (down to 10%), which reduced the tablet's overall size while also creating a porous tablet that is bioequivalent to conventionally manufactured immediate-release tablets and can be taken orally in a matter of seconds [28.29].

4.4. Constraints

Before using the technology, it may be necessary to take into account the aspects of size, feature details, surface finish, and print through error in the Z axis. Nonetheless, feature tolerances can be effectively controlled by designing the build in the machine so that the majority of features are built in the x and y axes as the material is laid down. In order to achieve mirror or exceptionally smooth finishes, surfaces typically need to be polished. Prior to use, the material density of a finished part or insert should be considered for production tooling. For instance, surface imperfections in injection molding inserts will result in imperfections in the plastic part; therefore, in order to avoid issues, the inserts must mate perfectly with the mold base in terms of temperature and surfaces. The removal of the metallic support structure and the post-processing of the produced part in this process take a lot of time and call for the use of EDM and/or grinding machines with the same level of accuracy as the RP machine. [29, 30]

Table 1: showing all available types of 3D Printers. [29, 30]

Type	Technologies	Materials
Extrusion	Fused deposition modeling (FDM)	Thermoplastics (e.g. PLA, ABS), eutectic metals, edible materials
Granular	Direct metal laser sintering (DMLS)	Almost any metal alloy
	Electron beam melting (EBM)	Titanium alloys
	Selective heat sintering (SHS)	Thermoplastic powder
	Selective laser sintering (SLS)	Thermoplastics, metal powders, ceramic powders
	Powder bed and inkjet head 3d printing, Plaster-based 3D printing (PP)	Plaster
Laminated	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
Light	Stereo-lithography (SLA)	Photopolymer

polymerized		
	Digital Light Processing (DLP)	liquid resin

5. Current and future applications of 3D Printing

5.1. Biomedical Engineering

Scientists and engineers have already been able to create body parts and organ parts using 3D printing technology in recent years. It is anticipated that in the upcoming years, the first complete organ made with 3D printing will be completed. The method for making the organ or body part is precisely the same as if it were made of plastic or metal, but biological cells produced in a lab are used as the raw material. It is guaranteed that the patient's body won't reject the organ since the cells are made especially for them. The creation of limbs and other body parts out of metal or other materials to replace lost or damaged limbs is another use for 3D printing in the biomedical industry. In many parts of the world, people who have been injured in war or by disease need prosthetic limbs. At the moment, prosthetic limbs are highly costly and typically not patient-specific. Custom prosthetic limbs are designed and made using 3D printing to satisfy the patient's exact specifications. The lost portion of that limb can be recreated by designers and engineers using a patient's body scan and the patient's existing bone structure [30].

5.2. Aerospace and Automobile Manufacturing

For a while now, high-tech businesses like aerospace and automakers have been using 3D printing as a tool for prototyping. But thanks to recent developments in 3D printing technology, it is now possible to produce functional parts that can be put through testing. Because the design cycle has significantly decreased, these companies are able to advance their designs more quickly than ever before thanks to the design and 3D printing process. The time it used to take for the design team to receive a physical prototype for testing and checks was months; today, it only takes a few hours. In these industries, 3D printing's future lies in producing functional parts straight out of the printer—not just for testing—for use in the finished product. For upcoming automobiles and aircraft, this procedure is already in progress. The layer-by-layer construction method of 3D printing enables the designer to construct the component precisely as required to complete the task at hand. A 3D printer can easily create extremely complex geometry, enabling parts that are stronger and lighter than their machined counterparts [31].

5.3. Medical applications

Customization and Personalization

The ability to create specialized medical gear and products is the biggest benefit that 3D printers offer in the field of medicine. For instance, patients and doctors can benefit greatly from the use of 3D printing to customize implants and prosthetics. Furthermore, customized jigs and fixtures for use in operating rooms can be produced via 3D printing. In terms of the amount of time needed for surgery, the recovery period for patients, and the outcome of the procedure or implant, custom-made implants, fixtures, and surgical instruments can be beneficial. It is also anticipated that 3D printing technologies will eventually allow drug dosage forms, release profiles, and dispensing to be customized for each patient. Since the early 2000s, when the technology was first used to create custom prosthetics and dental implants, 3D printing has been used in medicine. The uses of 3D printing in medicine have advanced significantly since then. The production of bones, ears, exoskeletons, windpipes, a jaw bone, eyeglasses, cell cultures, stem cells, blood vessels, vascular networks, tissues, and organs, as well as novel dosage forms and drug delivery devices, are all made possible by 3D printing, according to recently published reviews. Currently, 3D printing is being used in medicine for a number of broad purposes, including the creation of tissues and organs, implants, prosthetics, and anatomical models, as well as pharmaceutical research on drug delivery and dosage forms [32, 33, 34, 35].

6. Theoretical Scheme of 3D for drug manufacturing

Based on a patient's specific prescription from his doctor, a custom medication is designed *via* computer-aided design. The dosage form may be composed of complex geometries, multiple doses, or even multiple drugs. Drug-loaded bioink (biocompatible material) is then 3D printed on-demand *(fig 6).*

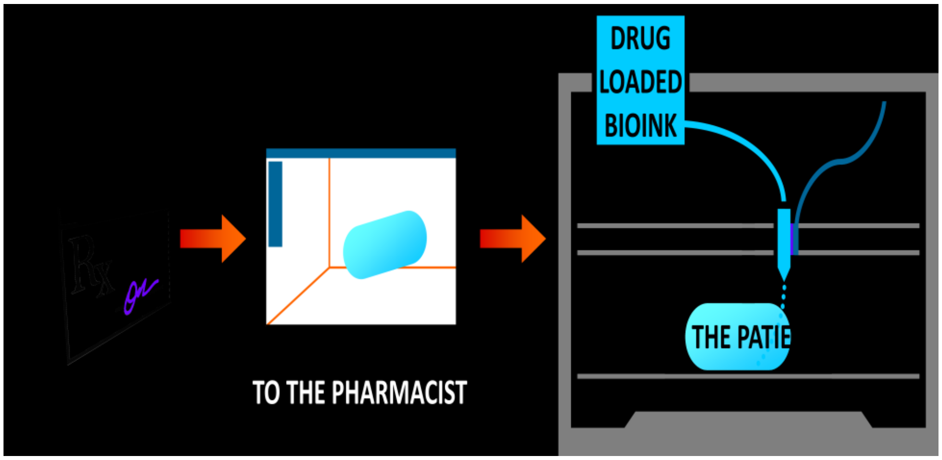

Figure 6: Theoretical scheme of 3D printing for drug manufacturing.

Benefits and Uses of 3DP in Pharmaceutical Drug Delivery: A variety of methods, including inkjet-based fabrication, Direct-Write, Zipdose, Thermal Inkjet (TIJ) printing, and Fused Deposition Modeling (FDM), can be used to fabricate 3D objects. A number of appealing features set 3DP apart from the conventional pharmaceutical product manufacturing process. These include: (a) high production rates because of its quick operating systems; (b) the capacity to achieve high drug-loading with much-needed precision and accuracy, particularly for potent drugs applied in small doses; (c) a reduction in material waste that can lower production costs; and (d) amenability to a wide range of pharmaceutical active ingredients, including those that are poorly water-soluble, peptides and proteins, as well as drugs with limited therapeutic windows.

It is expected that 3DP in pharmaceutical drug delivery will perform exceptionally well in the field of customized medications. The practice of pharmacy and medicine has entered a new era where "one size does not fit all," with prescriptions having to be customized to each patient's specific needs while accounting for variations in genetic profiles, age, race, gender, epigenetics, and environmental factors. In certain cases, treatment plans also need to be modified in order to increase patient adherence. This is crucial when treating chronic illnesses, as patients often have to adhere to intricate treatment plans that call for taking several medications at different times and frequently coordinating dosage schedules with adverse effects. 3DP technology can be used to achieve medicine customization in each of these scenarios. This is made possible by the flexibility in the development, design, and production of single- or multi-drug products that have integrated layers of controlled and immediate release that can be adjusted to suit the specific needs of individual patients.

Therefore, we hope that by using customized 3DP medications, medical practitioners will be able to take a patient's pharmacogenetic profile into account when deciding on a treatment plan. As the most widely used drug dosage form, it is expected that 3DP will continue to attract a lot of attention in solid dosage forms. Numerous factors, including ease of manufacturing, pain avoidance, accurate dosing, and the capacity to achieve patient adherence to treatment, contribute to the popularity of solid dosage forms. However, there are a number of issues with the multi-step manufacturing process of solid dosage forms, including long operating procedures, batch-to-batch variations because of operator judgment, material waste, low drug loading capacity, and suitability for only a small number of active ingredient categories. [18. 36.37.38.39].

Designing for 3D Printing

CAD software is required for the design of every part produced by a 3D printer. The accuracy of the printer and the caliber of the CAD design are the primary determinants of this kind of production. CAD software comes in a variety of forms; some are available for free, while others need a purchase or subscription. The specifications of the project you're designing will determine what kind of CAD software is best for you. However, any free CAD software program will work for novices who just want to learn the basics of CAD and create simple shapes and features.

When designing a part to be 3D printed the following points need to be kept in mind:

- The part needs to be a solid, that is, not just a surface; it needs to have a real volume.
- Creating very small, or delicate features may not be printed properly, this depends greatly on the type of 3D printer that is going to be used.
- Parts with overhanging features will need supports to be printed properly. This should be taken into account since after the model needs to be cleaned by removing the supports. This may not be an issue unless the part is very delicate, since it might break.
- Be sure to calibrate the 3D printer before using it, it is essential to ensure that the part sticks properly to the build plate. If it does not, at some point the part may come loose and ruin the entire print job.
- Some thought should be given to the orientation of the part, since some printers are more precise on the X and Y axes, then the Z axis. [40]

7. Conclusion and Future Perspectives

Our viewpoint on the benefits of 3D printing in drug production has been presented in this review. As suitable 3D printing techniques for pharmaceutical production, selective laser sintering, inkjet printing, and extrusion-based printing were demonstrated. For the purpose of drug loading and printing, solid filament materials as well as natural and synthetic hydrogels were examined. The ability to print precise and unique doses, control over the release characteristics of drugs, and the on-demand capabilities inherent in the printing approach were among the several justifications for the 3D printing of pharmaceuticals that were also put forth. For the pharmaceutical industry, 3D printing holds great promise for the future. When it comes to the direct-write fabrication of pharmaceuticals, medicine and healthcare have not yet fully tapped into the potential of 3D printing, despite the fact that a wide range of industries throughout society are following suit. This specific use of 3D printing will transform pharmacies, and we think that with further research, personalized medicine will reach new heights of potential.

3D printing has emerged as a practical and potentially revolutionary tool in several industries, including health. Applications have grown along with printer performance, resolution, and availability of materials. Scholars persistently enhance current medical applications utilizing 3D printing technology while also investigating novel ones. 6 3D printing has already produced significant and exciting medical advances, but some of the more ground-breaking uses, like organ printing, will take some time to develop. Since there are still a lot of unproven benefits associated with 3DP technology, it will take time, money, and vision to continue clinical development of this technology. We envision that in order to develop 3DP from a more clinically appealing standpoint, the following activities will take place: (i) software performance optimization and improvement; (ii) creation of new excipients or evaluation of existing excipients for use in 3D formulations; (iii) development and optimization of the manufacturing process for a variety of drug products; and (iv) clinical studies to evaluate the stability, safety, and efficacy of new 3D-based formulations. Aside from the expenses associated with creating new formulations or redesigning current formulations using 3DP, the inherent flexibility could be a significant source of risk from a safety perspective.

It is crucial to exclude drug or dose tampering during the procedure to guarantee that patients' treatment regimens are not mixed up or adulterated. Therefore, depending on the drug product, it is expected that regulatory concerns and the requirement for built-in tamper-proof strategies will have a significant impact on a broad-based application of 3DP in pharmaceutical drug delivery. It is also anticipated that regulatory stipulations for 3DP formulations will be strict in order to rule out illegal printing of drug products. It is crucial to remember that while 3DP is a flexible technique that can be used with a wide variety of pharmaceutical active ingredients, its effects on the physicochemical characteristics of drugs and excipients need to be determined case by case. This is due to the general knowledge that characteristics such as drug-excipient interaction, polymorphic changes, and dosage form stability all impact a drug's therapeutic efficacy. Combining 3DP with traditional pharmaceutical technologies is expected to accelerate the expansion of 3DP's potential applications in pharmaceutical drug delivery. These hybrid systems will take advantage of all the advantages of 3DP, including customization, precision, and decreased material waste, in addition to applying the tried-and-true efficacy of traditional pharmaceutical technologies.

In conclusion, 3DP technology opens the door to a new era of advanced drug delivery with built-in flexibility that is well suited for personalized/customized medicines. We believe that with patience and perseverance, 3DP will continue to revolutionize the development of new generations of pharmaceutical formulations that are safe and effective.

8. References

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