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3D Printing In The Pharmaceutical Industry: Disruptive Innovations And Emerging Trends

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The benefits and drawbacks of various 3D printing techniques are covered in the study. A thorough explanation of the many materials that work with each kind of 3D printing procedure is provided. The different application areas of each process type are also presented in the study. There is also a special section on industry 4.0. Despite the fact that 3D printing has advanced significantly, the literature review found that problems like material incompatibility and material cost still need to be resolved. Future studies could be conducted to improve and adapt the procedures to work with a variety of materials.Particularly in remote or resource-constrained areas where access to medical supplies is difficult in developing nations, this 3D printing technology or models can be used for specific healthcare tools, sophisticated disease diagnosis devices, ideal 3D models for surgical purposes, and on-site implants.3D printing software to create 3D mirror images of the surgical segment, significant financial waste, assembly time, and a host of difficulties can be prevented.This article summarises the current state-of-the-art 3D printing methods and the major benefits and motivations for using 3D printing in pharmaceuticals, highlighting the critical role that healthcare staff play, and will continue to play, in the future integration of 3D printing into the pharmaceutical sector.

Key Words:Three-dimensional(3D) Printing, Pharmaceutical Dosage Form, Personalized Medicine, Computer Aided Design, Sterolithography.

Introduction

The introduction of 3D printing has started to transform the present in both a technological and social sense. With the advent of 3D printed medications, food items, hardware, and even biological organs, we are gradually moving away from the two-dimensional realm of printing and towards a world of wonder. More attention needs to be paid to creating affordable printer technologies and materials that work with these printers in order to increase the variety of uses for 3D printed items.

When we think about manufacturing, the first thing that comes to mind is how we create things or transform raw materials into something that we can use, purchase, or consume in any way. Subtractive manufacturing is the initial method of production, in which we start with raw materials and work our way up to the final product. If a machine has the three characteristics of being three-dimensional, additive, and layer-based, it can be considered a 3D printer. Adding various components to create the desired substance is an additive process.

In 3D printing, which is fundamentally an additive manufacturing process,we start with the fundamental design of the part we wish to represent [1].A computer program that can be connected to 3D printers is used to construct the aforementioned design. After that, this software creates a unique file type that is transmitted to the printer. After reading that file, the 3D printer builds the product by superimposing one layer on top of the other [2]. Nearly all 3D processes

Layers are used in printing to create a portion. Instead of reading the parts as a single unit, 3D printers read them as a single two-dimensional layer at a time. The ability of 3D printers to read Standard Tessellation Language (STL) file types is the foundation for their operation. The technique of creating a 3D object of any shape from a 3D model or other electronic data sources using additive methods, which involve applying successive layers of material under a computer, is known as 3D printing or additive manufacturing (AM).Controls.[3]

Most people agree that Hideo Kodama of the Nayoga Municipal Industrial Research Institute produced the first tangible item from a computer design. Nonetheless, Charles Hull, who created the first 3D printer in 1984 while employed by the business heformed, 3D Systems Corp., is usually given credit for it. Charles a. Hull invented stereolithography, a solid imaging technique, and the STL (stereolithographic) file format, which is currently the most often usedformat in 3D printing today. He is also known for having developed 3D printing at the same time as he began commercial rapid prototyping. Initially, he employed ultraviolet-heated photopolymers to produce the melting and solidification action.[4] The technology has advanced since Charles W. Hull of 3D Systems Corp. created the first 3D printer in 1984, and these devices have grown in utility and affordability as their price points have decreased.

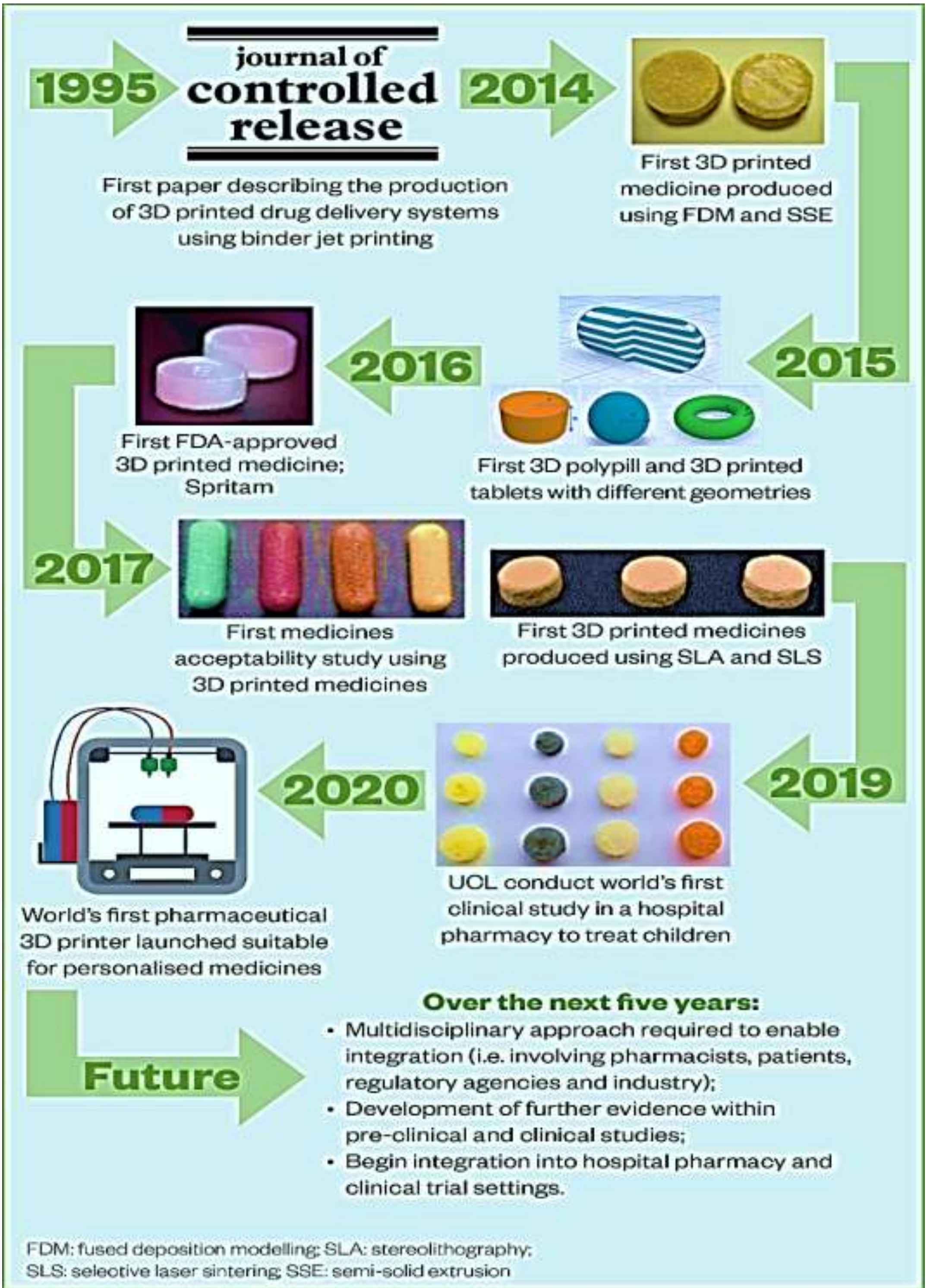
Advantage

- **Short production time:** as direct manufacturing begins with the 3D CAD model, no moulds or other tools are needed to get started. From design to finished product, production takes very little time. 3DPrinting generates the product very fast as compared to conventional procedures. With 3D printing, production time was shortened from months to days.

- **Cost-effective:** 3D printing allows for much faster production of goods. The cost of developing new products decreased significantly. The production run cost of this technique is relatively low.
- **Evaluation and feedback:** A prototype created using this method is put to the test in a variety of settings. It sells on a number of websites and receives feedback from customers to improve the product.
- **Easy Shearing:** The design's saved data file can be transferred quickly and simply around the world. Additionally, it makes it easier for specialists from around the world to share expertise and modify designs.
- **Material Waste:** Because the process is additive, relatively little material is wasted. Direct production is used to create the hollow section and holes. It also reduces the cost of machining and materials.
- **Reduce Risk:** Using 3D printed plastic to validate a design before spending a lot of money on a moulding tool is well worth the investment. 3D printing is significantly less expensive.
- **Develop your imagination:** The opportunities in the current explosion of digital art and design are not only growing faster but also boundless. Nowadays, practically everything that can be imagined may be 3D printed after being sketched out digitally or by another person. An idea, concept, dream, or invention can transform from a mere thought to a finished product in a comparatively short amount of time[5].

History of 3D Printing in Pharmaceutical Industry

Fig.1 History of 3D Printing



Need of 3D printing[6-9]

The use of 3D printing in pharmaceutical science can provide many benefits which includes – cost effectiveness; increased productivity; the democratization of design & manufacturing & enhanced collaboration.

- **Cost efficiency:** The most important benefits offered by 3D printing is the ability to produce items cheaply. Conventional method of drug manufacturing are less cost effective then 3D printing technology, because conventional methods uses a lots of process for manufacturing (mixing, milling, dry or wet granulation, compression or moulding etc.)
- **Enhanced Productivity:** traditional method of drug manufacturing uses various processes such as mixing, milling, dry or wet granulation, compression or molding that makes it time consuming. But 3D printing technology is much fasters than traditional method of drug manufacturing because it does not have various processes like traditional manufacturing. In addition to speed, other qualities, such as resolution, accuracy, reliability & repeatability of 3D printing technologies, are also improving.
- **Environment friendly**: 3D printing technology claims to have more environmental benefits than traditional drug manufacturing which needs huge setup to manufacture a pill. Another beneficial feature offered by 3D printing is the democratization of the design & manufacturing a goods.

Workflow in 3D Printing
The 3D printing technology workflow consists of the following steps: Design A virtual design of the 3D product model is developed using computer-aided design software, and the chemist can design the formulation [for example, size and

Fig.2 : Workflow in 3D printing

shape, etc.]. The chosen 3D printer receives the digital formulation, after which the design is digitally transferred and saved as a file. The programmer divides the file into several thin layers. Develop Print-lets are created by placing the necessary ink cartridge a combination of drugs and excipients into the chosen 3Dprinter, where it is solidified layer by layer on substate. The best printing settings (such as resolution, printing time, temperature, etc.) are chosen, often depending on the printer type, drug characteristics, and desired results. Dispense The final 3D product may require additional dusting, drying, polishing, etc., before the chemist may dispense it.The workflow involved in 3D printing is presented in Figure 2[10-11].

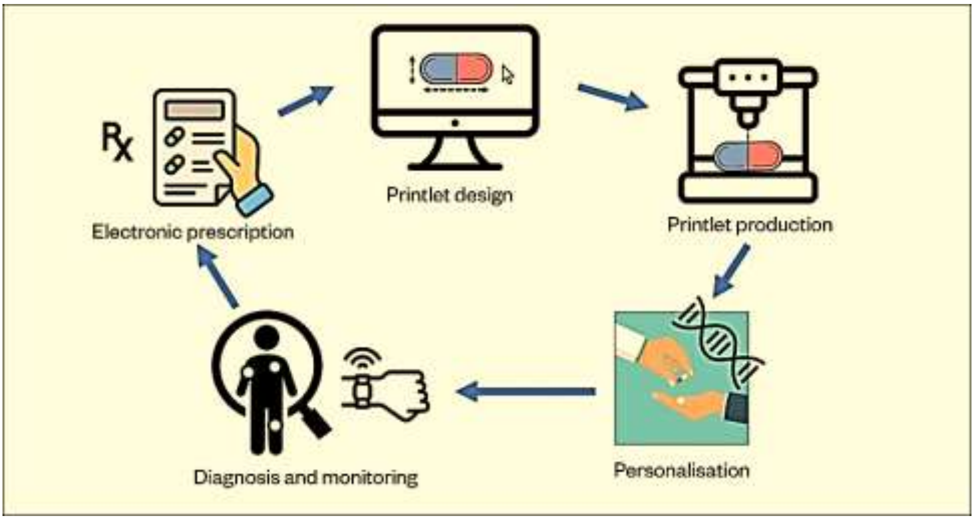


Fig.3: The five Component of a Digital Pharmacy Era[12]

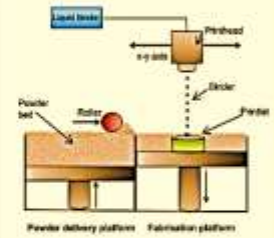
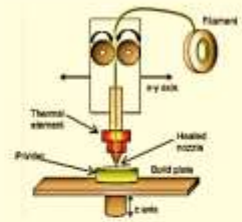
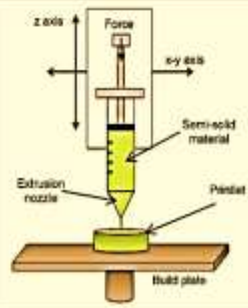
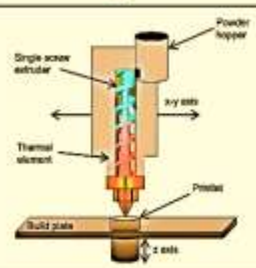
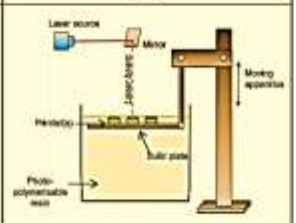
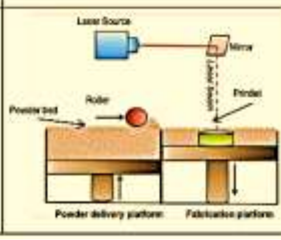
Working of 3D printer :

The basic process involves 3D prototyping of layer by layer fabrication to drug excipients to formulate into the desired dosage form. It begins with making a virtual design is for instance a CAD (Computer aided Design) file. This CAD file is created using a 3D modelling application or with a 3D scanner (to copy an existing object). A 3D scanner can make a 3D digital copy of an object

Steps involved in 3D printing:

- Design: The intended product design is digitally rendered. Design can be rendered in 3 dimensional with Computer Aided Design Software (CAD)
- Conversion of the design to a machine readable:3D design are typically converted to the STL file format, which describe the external surface of a 3D model.
- Raw material processing: Raw material may be proceed into granules filaments, or binder solution to facilitate the printing process.
- Printing: Raw materials are added and solidified in an automatic, layer –by-layer manner to produce the desired product.
    - Removable & post processing: After printing products may require drying, sintering, polishing or other post processing steps[13-15].

Table 1: The six main 3D printing technologies used in pharmaceuticals, detailing the mode of action, types of formulations produced and a diagram of the printing process for medicines production[16].

3D printer	Mode of action	Advantages	Disadvantages	Schematic
Binder jet printing	A nozzle containing a binder liquid moves along an x-y axis depositing the liquid onto a flat powder surface. The liquid binds the powder particles together, causing layer solidification. The fabrication build plate is then moved down along the vertical z-axis. A thin powder layer is distributed on top and the process is repeated sequentially to fabricate a 3D-printed medicine	• Capable of producing delayed release and zero order release (a drug released at a constant rate) formulations; • Used to develop the world's first US Food and Drug Administration (FDA)-approved 3D printed medicine; • Capable of producing immediate- and sustained-release formulations; • High resolution enables the formation of complex geometries.	• Expensive process; • Lack of portable equipment.	
Fused deposition modelling	A drug-loaded filament is extruded through a heated nozzle. The printer head is moved along the x-y axis to release the molten extrudate, which solidifies at room temperature onto a build plate. The build plate is sequentially lowered along the vertical z-axis to enable a layer-by-layer fabrication of a 3D-printed medicine	• Capable of producing immediate and sustained-release formulations; • Can improve solubility of poorly soluble drugs (by producing amorphous solid dispersions); • Ability for multi-nozzle printing (production of multi-drug combinations); • Cheap system; • Portable, compact and user friendly.	• May be unsuitable for thermosensitive drugs; • Can be challenging to formulate the initial filament feedstock; • Challenging to scale up; • Low drug loading.	
Semi-solid extrusion	A drug-loaded semi-solid material (e.g. gel or paste) is extruded using a syringe-based tool head. The printer head is moved along the x-y-z axis to release the extrudate, which solidifies at room temperature onto a build plate	• Suitable for production of chewable and palatable formulations; • Capable of producing a range of formulation types, including immediate-release and controlled-release dosage forms, polypills and oral films.	• Low resolution compared to other 3D printing technologies; • Only suitable for drugs that can be formulated as a semi-solid; • Low throughput.	
Direct powder extrusion	An extrusion-based process, a drug-loaded formulation blend is inserted into a powder hopper. The hopper feeds into a heated single screw extruder in the print head, creating a molten extrudate, which solidifies at room temperature onto a build plate. The build plate is sequentially lowered along the vertical z-axis to enable a layer-by-layer fabrication of a 3D-printed medicine	• Capable of producing immediate- and sustained-release formulations; • Can improve solubility of poorly soluble drugs (by producing amorphous solid dispersions); • Capable for scale up (demonstrated by Triastek, which developed a FDA investigational new drug application clearance for a formulation prepared using a similar technology).	• May be unsuitable for thermosensitive drugs; • Relatively new 3D printing technology in pharmaceuticals.	
Stereo-lithography	The process involves exposing a photopolymerisable resin to high-energy light (e.g. UV light) to induce polymerisation and solidification of the material. Each time, the resin is solidified to a defined depth, the platform is moved down vertically along the z-axis and the built layer is recoated with resin. The process is repeated to create a 3D-printed medicine	• Widely explored for the production of sustained-release drug products and medical devices; • High resolution and accuracy (superior to other 3D printing technologies) enabling the production of complex geometries; • Can improve solubility of poorly soluble drugs; • Suitable for the production of multi-layered polypills.	• May be unsuitable for photosensitive drugs; • Potential issues around material toxicity.	
Selective laser sintering	This process employs a laser that is directed to draw a specific pattern on the powder bed, causing selective partial or full melting to bind powder particles. Once the layer is sintered, a roller distributes a fresh layer of powder on top of the sintered material. The process is repeated layer-by-layer to fabricate a 3D-printed medicine	• Capable of forming highly porous dosage forms (rapidly dissolving); • Capable of producing a range of formulation types, including immediate-release through to controlled-release dosage forms and medical devices; • High resolution process enabling the production of complex geometries; • Suitable for the production of polypills.	• May be unsuitable for photosensitive and thermosensitive drugs; • Requires precise control over powder flow characteristics; • Post-processing required.	

Typesofprocessesin3D printing

AM techniques have been developed to meet the demand for printing complex models with high resolutions. Rapid prototyping has contributed significantly to the development of AM technology. Am technologies are divided into three primary categories: sintering, which involves raising the temperature of the material without liquefying it to create intricate, high-resolution prototypes; melting, which involves melting powders with electron beams; and stereolithography, which employs a process called photopolymerization that makes use of an ultraviolet laser. Torque-resistant ceramic components are prepared to withstand the highest temperatures by dismissing this laser over a photopolymer resin vat.

Stereolithography (SL)

The first 3D printers to be put into service were stereolithographic/SL machines that were usedTo create 3D models, 3D prototypes, 3D parts, and patterns. The 3D printing era began in the late 1920s, and SL is the first 3D printing technology ever offered to the market. Charles Hull created and copyrighted 3D printing in 1984, despite the fact that a lot of research in this field was done in the 1970s [17].

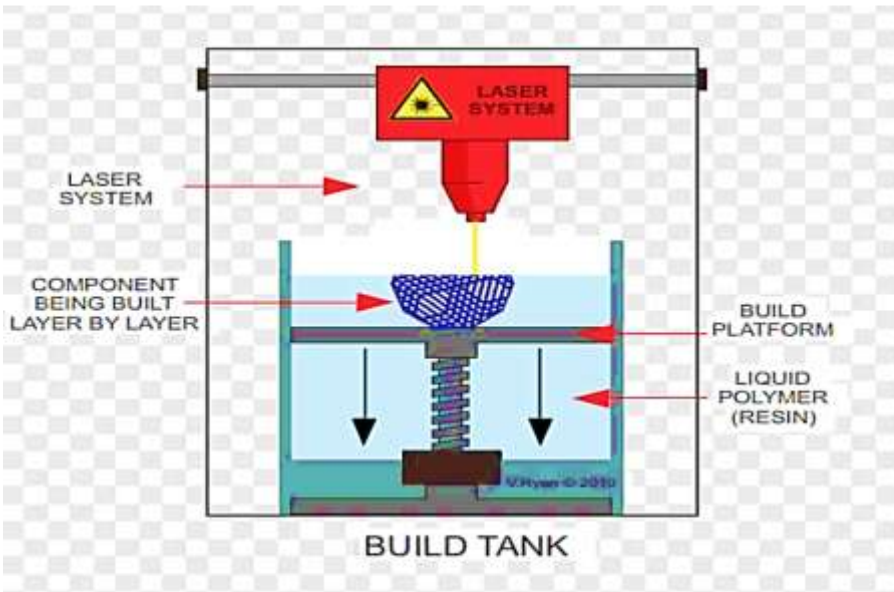


Fig.4: Stereolithography (SL)

Understanding the operation of the SL process is necessary before defining the word. A CAD file is created on the system and converted to an STL file format to start the procedure. The geometric information needed for a 3D printer to create an object is provided by this sort of STL file. A computer for process control, a laser source, a perforated table, and ultraviolet (UV) curable photopolymer liquid are the four primary components that go into the formulation. 3D printers begin operating in such a manner that the perforated table is submerged in the liquid tank after they have read the kind of STL file.

Selectivity Laser Sintering

DARPA's backing, Dr.Carl Deckard and Dr. Joe Beaman, an academic adviser at the University of Texas, created and patented selective laser sintering (SLS) in the middle of the 1980s.[7] In order to design and construct the selective laser sintering machines, Deckard was a part of the subsequent start-up business, DTM. The largest rival of DTM, 3D Systems, purchased DTM in 2001. Deckard's selective laser sintering process was the subject of the most recent patent, which was granted in January 1997 and expired in January 2014. A 3D printing method called selective laser sintering employs a laser as the power source to sinter powdered material, primarily metal, by pointing the laser to certain locations in space specified by a 3D model and binding the material to make.

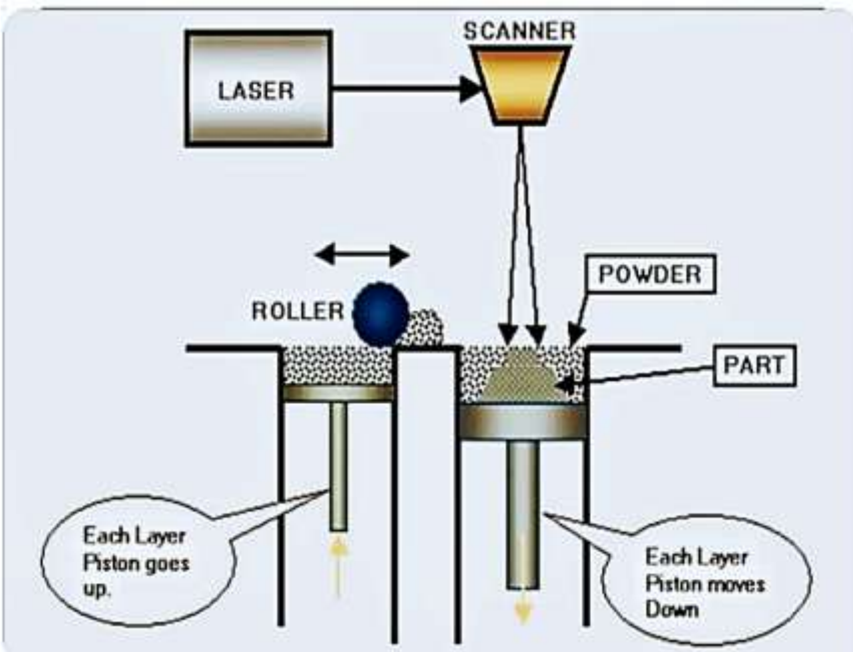


Fig.5: Selectivity Laser Sintering

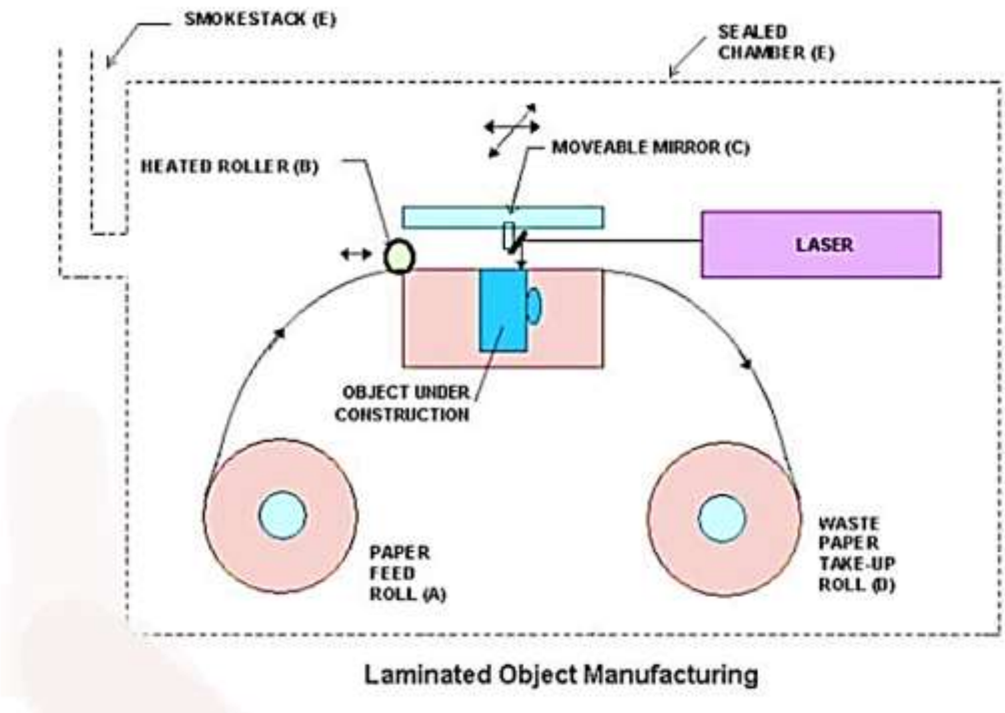
A solid structure. Selective laser melting uses a comparable concept, but in SLM the material is fully melted than sintered, allowing different properties (crystal structure, porosity). SLS is a relatively new technology that so far has mainly been used for additive manufacturing and

for low-volume production of parts. Production roles are expanding as the commercialization of additive manufacturing technology[18].

Laminated objectmanufacturing (LOM)

Helisys Inc.(now Cubic Technologies) in 1991 headquartered in California, commercialised LOM [8]. This method of rapid prototyping creates models using laminates of paper, plastic, or metal that are successfully epoxied together. A laser cutter is then used to cut the model or item into the appropriate shape. The first step in the procedure is to use a heated roller to adhere a sheet to a substrate. Next, using a laser or a mechanical cutter, the subsequent layers are precisely cut and glued one after the other, or forming first, then bonding [9]. the platform with the finished layers moves downward, the modern sheet of metal is rolled into place, and the platform returns to its starting position to take in the subsequent layer. The process must be carried out till the prototype is created. Lamination, ultrasonic metal seam joining, and CNC machining may be combined in UAM, a subset of LOM [19].

Fig.6: Laminated object manufacturing (LOM)



Direct energy deposition

(DED) alternative 3D printing techniques, which are used for maintenance and repair rather than component production. By melting material as it is deposited, DED techniques facilitate the creation of materials . Two powder feed nozzles and the deposition head, which integrates an energy source, make up the apparatus utilised in the DED process. Either a fine wire or metal powder can be put into this operation. The specific component that needs to be made is stored on a platform, and occasionally there is also inert gas tubing.

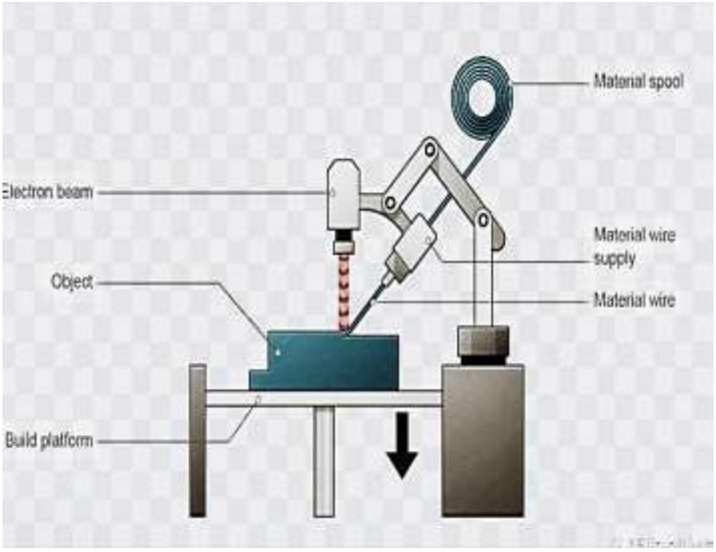


Fig.7: Direct energy deposition

The position head is a four or five axis machine that deposits the powder beam and simultaneously the laser beam. Using a central heat source (either an electron beam or a laser), the DED technique fixes and creates new material objects on existing products by adhering the material layer by layer as it solidifies[20].

Binder jetting (BJ)

Inkjet technology is modified for use in binder jetting. This procedure was first used at the Massachusetts Institute of Technology (MIT) [12]. An inkjet is used in this process to bind the objects rather than lasers. It uses a 2D printer technology in inkjet and goes up in layers forming a 3D project. In this process, with the help of a printhead, moving on two axes, a liquid binder is precisely deposited. This process also begins like any other 3Dprinting process, that is by creating a 3D drawing and then importing it into printer software. Since constant supply is required during printing, thus, a dispenser ensures that supply by placing powder in it that is to be used.

The printing head attaches the binder in accordance with the specifications after applying a powder sheet of different thickness. The solvent containing the binder is desiccated using electric or fluorescent lamps before moving on to the next layer. Then, the powder bed is de-escalated and a fresh sheet of powder is applied. The binder is then put in a furnace at the end of the cycle; the temperature and duration needed depend on the type of binder used. The metals and ceramic components must unHot isostaticpressing prior to use, however the majority of metals and plastics are ready to use right out of the printing systems and don't need any post-processing [13].

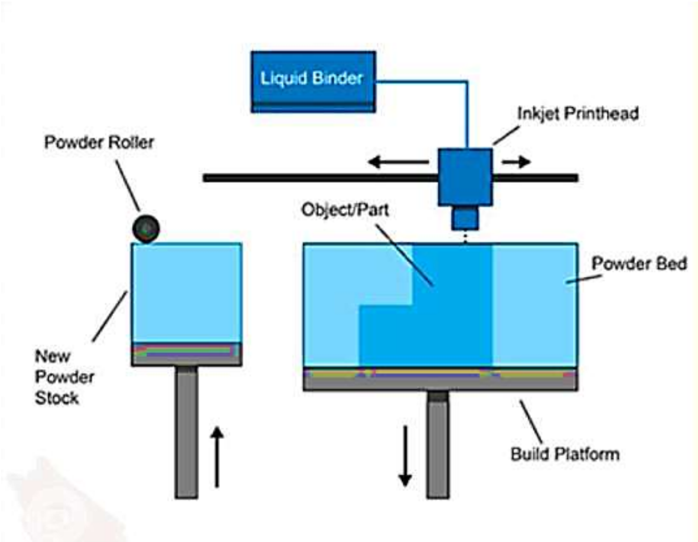


Fig.8: Binder jetting (BJ)

The role of pharmacy in 3D printing

In order to facilitate the use of 3D printing for pharmaceuticals, chemists and pharmacy technicians from a variety of industries—including academia, business, government, and regulatory bodies—are essential.Academic pharmacists from UCL School of Pharmacy spearheaded the first research that investigated the use of FDM, SLA, and SLS 3D printing for the production of medications in 2014, 2016, and 2017, respectively. Other pharmacy schools worldwide are investigating a similar idea[19].

It Is imperative that the next generation of pharmacists, especially preregistration pharmacists and M.Pharm students, receive training on the safe and efficient use of this technology in the workplace[21].

Modifying model parameters like size, shape, or fill rate, three-dimensional printing technology can be utilised to print specific medications. Low-dose customised medications that are appropriate for children can be made using 3D printing technology, and the medications' flavour and look can be enhanced to improve paediatric patients' compliance[16-19].

3D printing technology offers substantial benefits in personalised medicine manufacturing when compared to conventional drug preparation methods. It makes it simple to manufacture preparations with intricate structures or drug release behaviours and enables quick production of small quantities of medications.In order to lower its softening point and improve thermoplasticity, EC is typically employed in 3DP in conjunction with plasticisers or softeningagents. When using low molecular weight EC, the latter is preferable to higher MW grades. When 3DP objects are produced at a temperature higher than the EC softening temperature (156°C), oxidation may occur; however, this phenomena can be prevented by employing antioxidants[22].

Role of 3D printing in the pharmaceutical assiduity is fleetly evolving and has the implicit to revise the way drugs are developed, manufactured, and delivered to cases. Then are some ways 3D printing is impacting the pharmaceutical assiduity.

1. **Personalized Medicine:-** 3D printing enables the creation of substantiated drugs with specific boluses, shapes, and sizes acclimatized to individual cases' requirements. This can ameliorate treatment issues and reduce side goods.
2. **Complex Lozenge Forms:-** 3D printing can produce complex lozenge forms, similar as tablets with multiple layers or unique shapes, which can ameliorate medicine release biographies and bioavailability[6].
3. **Oral Solid Lozenge Forms:-** 3D printing can produce oral solid lozenge forms, similar as tablets and capsules, with precise control over the expression and manufacturing process.
4. **Implantable bias:-** 3D printing can produce implantable bias, similar as medicine- eluting stents and implantable medicine delivery systems, which can give targeted and sustained medicine release.
5. **Towel Engineering:-** 3D printing can produce towel- finagled products, similar as skin and cartilage, which can be used for crack mending and towel form.
6. **Pharmaceutical Research and Development:-** 3D printing can accelerate pharmaceutical exploration and development by enabling the rapid-fire creation of prototypes and testing of new phrasings and bias[11].
7. **Force Chain Optimization:-** 3D printing can optimize the pharmaceutical force chain by enabling the original product of drugs, reducing transportation costs and lead times.
8. **Case-Specific Modeling:-** 3D printing can produce patient-specific models, similar as anatomical models, which can be used for surgical planning and training.
9. **Cost Reduction:-** 3D printing can reduce costs associated with pharmaceutical development and manufacturing, similar as those related to tooling, molding, and packaging[22-24].

Some of the crucial benefits of 3D printing in the pharmaceutical assiduity include

- **Increased perfection and delicacy:-** 3D printing enables the creation of complex shapes and precise control over the expression and manufacturing process.
- **Advanced case issues:-** 3D printing can lead to advanced treatment issues and reduced side goods through substantiated drug and targeted medicine delivery.
- **Reduced costs:-** 3D printing can reduce costs associated with pharmaceutical development and manufacturing.
- **Increased effectiveness:-** 3D printing can accelerate pharmaceutical exploration and development and optimize the force chain.

Still, there are also challenges and limitations to the relinquishment of 3D printing in the pharmaceutical assiduity, including

- **Regulatory fabrics:-** Regulatory fabrics for 3D printing in the pharmaceutical assiduity are still evolving and need to be clarified.
- **Quality control:-** icing the quality and thickness of 3D- published pharmaceutical products is a significant challenge.
- **Scalability:-** 3D printing is still a fairly slow and labor-ferocious process, which can limit its scalability for large- scale pharmaceutical product.
- **Intellectual property:-** guarding intellectual property related to 3D printing in the pharmaceutical assiduity is a concern.

Overall, 3D printing has the implicit to transfigure the pharmaceutical assiduity by enabling the creation of substantiated drugs, complex lozenge forms, and implantable bias, and by perfecting patient issues, reducing costs, and adding effectiveness[23-28].

Application of 3D printing

1. **Intratumoral drug-eluting implants In the group of intratumoral implants:** A comparably large number of manuscripts was published in the time frame chosen for the authors' literature research with the applied keywords. It is noticeable, that among the methods used for 3D printing MEX (SE) is the most prominent method used in this category. Only two published manuscripts used MEX (FE) setups and only two reports of VPP were identified. Some authors referred to specific tumor locations such as breast, brain, liver, ovarian or prostate tumors whereas others did not specify this. In most publications, authors assumed that a solid tumor was surgically removed and the implant would be inserted into the resurrection site in order to prevent tumor re-growth caused by incomplete tumor removal. The benefit of 3D printing for this site was generally described as the flexibility to adapt the implant size and shape to the operational space in combination with a flexibility regarding drug (s), doses and release rates. Some authors also aimed at a triggered release by an external stimulus, e.g. [21,22] or at an additional therapy option such as a layer containing particles intended to enhance radiation therapy [23].
2. **Dental:** Traditional dental devices, such as dental trays and orthodontic re-tainers, have primarily been used for maintaining teeth alignment after orthodontic treatment. These devices are typically custom fitted to the patient's dentition and are made using molds taken directly from the patient's teeth. However, 3D printing offers a transformative approach to the design and production of these dental devices, enabling greater customization, more efficient manufacturing processes, and the potetial for drug delivery directly from the device.

   Three manuscripts have been identified that explore the application of 3D printing in dental dosage forms, specifically focusing on dental trays and orthodontic retainers . These studies demon-strate the potential for these devices to deliver both local and systemic treatments. Jiang et al. investigated the incorporation of clonidine hydrochloride into a 3D printed orthodontic retainer designed for long-term drug administration.

The study utilized a previous mold of a volunteer's teeth to capture the individual teeth orientation, which was then scanned and transferred to a CAD file to produce a customized retainer . The retainer was printed using a combination of PLA and PCL in an 8:2 ratio to achieve the necessary mechanical strength, while small amounts of macrogol 4000 and polysorbate 80 were added to modify printability and drug release characteristics.

Drug release was sustained over a period of a few days, though the exact amount of drug released depen-ded on the duration of wear, highlighting a challenge in the application of drug-loaded retainers. Unlike traditional orthodontic retainers,which are worn multiple times, often overnight, this drug-loaded retainer was designed for single use only due to the one-time release of the drug [24].

3. **Pellets and minitablets:** While pellets and minitablets describe different dosage forms and their conventional production is very different, they will be described together in this review due to their similar dimensions and the resulting requirements and challenges.
4. **Delayed-release tablets:** DR tablets are tablets in which the onset of release is adjusted by the formulation design. This includes gastro-resistant dosage forms, which typically show a pH-dependent drug release. Gastro-resistance can be beneficial as some drugs are not stable inside the acidic environment of the stomach or even harm the stomach mucosa [Other DR for-mulations aim at releasing drugs at a specific, more distal portion of the intestine, e.g., the colon. This is often also called targeted release. Tar-getting of specific regions, for example the colon, can have a positive effect especially when a local treatment at a specific site is desired as smaller doses are typically required which can lead to fewer adverse effects
5. **Ophthalmic :** According to the Ph. Eu., include eye drops, eye lotions, semi-solid eye preparations, and ophthalmic inserts, which are often limited by their short duration of action, requiring frequent administration to maintain therapeutic levels. To address this issue, 3D printing has been explored as a means to create longer-acting dosage forms that could enhance patient compliance and improve treatment outcomes. In this review, various 3D printed ophthalmic dosage forms, including contact lenses, ophthalmic patches, inserts, and hydrogel scaffolds, were investigated[25-30].

Table 2 : Process,applications,materials,benefitsanddrawbacks[9,13,17,26]

S. No.	Method	Material	Application	Benefits	Drawbacks
01	Fused Deposition Modelling	Continuous filaments of thermoplastic polymers, fiber-reinforced continuous polymerics.	Rapid prototyping of advanced composite parts and toys.	Reduced cost, increased speed, easy to use.	Poor mechanical properties, confined material.

02	Power Bed Fusion	Compressed fine powder components, limited polymerics, metals & alloys	Medicinal electronic, aviation and structure.	High resolution good quality.	Prints slowly expensive cost, high porosity
03	Laminated Object Manufacturing	Polymer, metal-filled tapes, ceramics, metal rolls and composites.	Paper making, foundry sector, smart structures.	Reduced tooling economical, perfect for generating larger systems.	Low accuracy, poor surface finish, limitation for complex printing with fine details & shapes.
04	Direct Energy Deposition	Alloys and metals in the form of wire or powder, polymers and ceramics.	Aerospace, retrofitting, repair, cladding, biomedical.	Low cost and time, good mechanical properties, accurate regulation of composition, outstanding for repair	Low accuracy, poor surface finish, limitation for complex printing with fine details & shapes.
05	Stereolithography	A photo-active resin monomers, polymer-ceramics hybrid.	Biomedical models.	High resolution, premium-quality results.	Very few materials, prints slowly, expensive costs.
06	Binder Jetting	Metals, sand and ceramics that are granular in shape.	Fabrication of full-color prototype and wide sand casting cores and moulds.	Low-cost, quick, simple and cheap.	Low density, shrinkage without infiltration.

Future Prospects

New possibilities in 3D printing may open up whole new opportunities for pharmaceutical research and bio-technology applications. In near future 3D printing approach will be utilized in many ways such as fabricate and engineer various novel dosage forms, achieve optimized drug release profiles, develop new excipients, avoid incompatibilities between multiple drugs, drug dosage forms, supporting delivery, limit degradation of biological molecules or helping to research cures. 3D printing could add a whole new dimension of possibilities to personalized medicine. In its most simplistic form, the idea of experts and researchers is to produce personalized 3D printed oral tablets. 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. In future it may lead to the innovation in garage biology. As the technology is still so new, there's a lack of regulation, safety and security concerns of 3D printing. So these problems can be overcome in nearby future.

Table 3: Shows some 3D Printing Technologies and Pharmaceutical Formulation For Drug Delivery

3DP Technology	Dosage Forms	Active Ingredients
Fused Deposition Modelling (FDM)	Tablet	5-aminosalicylic acid (5-ASA, mesalazine) and 4-aminosalicylic acid (4-ASA)
3DP extrusion-based printing	Tablet	Captopril with Nifedipine and Glipizide
3DP machine	Multi-drug implant	Rifampicin and Isoniazid
Desktop 3D printer	Tablet	Guaifenesin
3DP technology	Tablet	Acetaminophen
Inkjet 3DP	Nanosuspension	Folic Acid
Inkjet 3DP	Implant	Levofloxacin
Thermal Inkjet (TIJ) Printing	Solid dosage forms	Prednisolone
3D Extrusion Printing	Encapsulated within a polymer (PLGA) poly(vinyl alcohol) (PVA)	Dexamethasone- 21-phosphate disodium salt
Thermal Inkjet (TIJ) Printing	Solution	Salbutamol sulphate
Inkjet 3DP	Nanoparticles	Rifampicin
FDM	Tablet	Hydrochlorothiazide
(FDM) and Hot Melt Extrusion (HME)	Tablet	Domperidone, hydroxypropyl cellulose (HPC)
FDM	Tablet	Nitrofurantoin, polylactic acid and hydroxypropyl methylcellulose
3D printed	Biodegradable patch	poly(lactide-co-glycolide), polycaprolactone, and 5-fluorouracil

Conclusion

3D printing technology may improve its applications in Pharmaceutical Research and Biotechnological fields.3D printing involves wide technical range in pharmaceutical eld with novel drug delivery system, generation of new excipients, improvements of drug compatibility and customized dosage forms.3D printing is likely to be introduced in hospitals, pharmacies, oreven houses for drug dispensing. Therefore, pharmacists, who are the main users, have to prepare their knowledge and skills for this future area of work. (26). 3D Printing technology is emerging as a new horizon for advanced drug delivery with built-in flexibility that is well suited for personalized/customized medication.3D printing has revolutionized the way in which manufacturing is done. It improves the design manufacturing and reduces lead time and tooling cost for new products. This chapter has summarized different fabrication methods and some notable applications of 3D printing in the healthcare sector, especially in pharmaceutical science.It has greatly enhanced the product and parcels of new forms similar as orodispersible tablets, gastro floating tablets and polypills. The quick product of customised models is unique to AM and can be employed in areas similar as personalised implants and bioengineering models.As an arising technology, the enrollment and form path for 3D- published medications is unique, while intellectual property rights, medicine regulations, and other programs or regulations are still breaking new ground. Overall, this review aims at reflecting the current development status, artificial characteristics, and overall development trends of 3D- published medicines. It's believed that with nonstop sweats, the future of the 3D- published medicine assiduity is promising and will clearly promote medicine medication technology that's intelligent and substantiated. Their development history, and the advance results achieved, driving the invention of medicine development models.It can transition conventional means of drug mass manufacture towards the product of small batches of largely flexible and personalised lozenge forms on- demand. This technology provides benefits for cases, druggists and the pharmaceutical assiduity likewise by furnishing unique advantages similar as making treatments safer and further effective.

Still, there's still a significant hedge to insure that 3D published drugs have the same efficacity, safety, and stability as the medicinal conventionally manufactured by the Pharmaceutical Industry. The establishment of guidelines, laws, quality systems of 3D printing drugs.

The FDA guidance entitled "Technical Considerations for Additive Manufactured bias" FDA's original thinking on specialized considerations associated with the processes, and recommendations for testing and the characterization for bias that include at least one cumulative manufacturing fabrication step.

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