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Review Article Topic - 3D Printing In Pharmaceutical Industry

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Objectives –

1. **Personalized Medicine -** Tailor drug doses, formulations and delivery systems to individual patient needs, improving treatment outcomes and patient compliance.[26]
2. **Sophisticated drug delivery systems -** Precisely develop advanced drug delivery devices such as implants, capsules and patches. Control the kinetics of drug release, improving therapeutic efficacy and safety.[27]
3. **Rapid prototyping -**Accelerate the creation and testing of new dosage forms, dosage forms and prototype medical devices by reducing development timelines and costs.[28]
4. **Clinical models and simulations -**Create anatomically accurate models of organs, tissues, and disease structures for preclinical testing, for drug efficacy research and medical training, minimizing reliance on animal testing.[29]
5. **Scale manufacturing -**Possible on-site or distributed manufacturing of drugs, enabling small batch production and reduced inventory and faster response to market demands.[30]
6. **Combination Therapies -** Develop multiple drugs and combination therapies in a single dosage form, improving treatment, efficacy, comfort and patient compliance.[31]
7. **Surgical Guides and Implants -** Produce patient specific surgical guides, implants and prostheses. In precision medicine applications such as orthopedics, dentistry, and regenerative surgery.[32]
8. **Regulatory compliance -** Ensure that 3D printing processes and products meet regulatory requirements for safety, quality, and consistency (e.g., FDA guidelines).[33]
9. **Supply chain resilience-** Improve pharmaceutical supply chains by reducing reliance on centralized manufacturing facilities, mitigating supply disruptions and improving inventory management.[34]
10. **Patient Education and Engagement -** Use 3D printed models and visual aids to improve patient understanding of disease, treatment options and medication delivery and promote better healthcare. Outcomes and adherence.[35]

Together, these Objectives to transform the pharmaceutical industry by leveraging the capabilities of 3D printing technology to address clinical needs, improve healthcare and advance medical innovation.

Methodology –

In the pharmaceutical industry, 3D printing, also known as additive manufacturing, is utilized for various purposes, including the fabrication of personalized medication, drug delivery systems, and dosage forms. The methodology used in 3D printing within the pharmaceutical industry involves several key steps:[36]

1. **Design and Formulation:**

Drug Selection: Choose an appropriate active pharmaceutical ingredient (API) for the desired therapeutic effect.
Excipient Selection: Select suitable excipients (inactive ingredients) to optimize drug delivery, stability, and release profile.
Formulation Development: Develop a formulation that incorporates the API and excipients into a printable material, ensuring compatibility with the 3D printing process.

2. **Printing Material Preparation:**

Material Selection: Choose a printing material compatible with pharmaceutical applications, such as pharmaceutical-grade polymers or hydrogels.

Material Characterization: Characterize the physical and chemical properties of the printing material to ensure suitability for 3D printing and pharmaceutical use.

3. **Printing Process:**
Preparation of Printing Material: Load the printing material into the 3D printer's reservoir or cartridge.
Layer-by-Layer Deposition: Utilize a suitable 3D printing technology (e.g., FDM, SLA, SLS) to deposit successive layers of material based on the digital design.
Incorporation of API: Integrate the API into the printed dosage form at precise locations and concentrations to achieve the desired drug release profile.
Controlled Drug Dispensing: Employ precise control mechanisms to ensure accurate dosing and distribution of the API within the printed structure.

4. **Post-Processing:**
Curing and Solidification: Post-process the printed dosage form to enhance mechanical strength, stability, and drug release properties.
Surface Finishing: Perform finishing steps such as polishing or coating to improve the aesthetics and patient acceptance of the printed dosage form.

5. **Quality Control and Assurance:**
In-Process Monitoring: Monitor critical parameters during the printing process, such as temperature, layer thickness, and material flow rate.
Physical and Chemical Characterization: Conduct comprehensive testing to evaluate the physical properties, drug content, and release kinetics of the printed dosage forms.
Biological Evaluation: Assess the biocompatibility and safety of the printed pharmaceutical products through in vitro and in vivo studies.

6. **Regulatory Compliance:**
Documentation and Validation: Prepare detailed documentation of the manufacturing process and conduct validation studies to ensure compliance with regulatory requirements.
Regulatory Submission: Compile the necessary data and documentation to support regulatory submissions for approval of the 3D printed pharmaceutical products.

7. **Scale-Up and Commercialization :**
Process Optimization: Optimize the 3D printing process parameters and manufacturing protocols for scalability and reproducibility.
Good Manufacturing Practices (GMP): Implement GMP standards to ensure the quality, safety, and consistency of the printed pharmaceutical products during commercial-scale production.
Market Entry: Launch the 3D printed pharmaceutical products into the market, considering factors such as pricing, distribution, and market acceptance.

By following this methodology, pharmaceutical companies can harness the potential of 3D printing to develop innovative drug delivery solutions tailored to patient needs while meeting regulatory standards and ensuring product quality and safety.

ABSTRACT :3D printing is a revolutionary technology that uses computer-aided design software and programming to create three-dimensional objects by placing material on a platform. 3D printing is an additive manufacturing technique where successive layers of material are layered or solidified to form a 3D structure. The drugs are configured in three dimensions by a computer-aided design module and converted into a machine-readable form that references the outer surface of the 3D dosage form, which then cuts that surface into several different printable coating layers and transfers those layers to the 3D. a machine Various 3D printing technologies have been developed and developed to produce new solid dosage forms, which are the most familiar and characteristic products today. The pharmaceutical industry wants to support the 3D printing process and explore the wonders of this approach. 3D printing can have completely new possibilities for optimizing medicine. The purpose of this review is to introduce different methods (thermal inkjet printing, inkjet printing, melt deposition modeling, extrusion 3D printing, pull dose, hot extrusion, 3D printer, stereolithography, selective laser sintering, laser-based writing system, continuous layer interface manufacturing, powder-based 3D printing), 3D printer advantages, limitations, applications in medical technology. [25]

I. INTRODUCTION

3D printing is an additive manufacturing (AM) technology that involves layer-by-layer material deposition in a predetermined cross-section. It develops customized complicated geometries and shapes to provide a one-of-a-kind drug release pattern ideal for personalized therapy. This study discusses several 3D printing processes such as Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), Semi-solid extrusion (SSE), Stereolithographic (SLA), Thermal Inkjet

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(TIJ) Printing, and Binder Jetting 3D Printing, as well as its applications in medicine. The "one-size-fits-all" approach underpins most conventional therapies. This is not always true; it is possible that the medicine used to treat one patient causes negative effects in another.During the current COVID-19 pandemic, 3D printing technology has been employed to generate Copper 3D Nano Hack masks, High-Efficiency Particulate Air (HEPA) masks, Lowell masks, hospital respiratory support gadgets PPE kits, and even mask adaptors.[1]

History

Chuck Hull patented the first three-dimensional printer in the 1980s. It employed a method he dubbed stereo lithography (SLA), which is still in use today. Hull's printer was referred to in his 1986 patent as a "Apparatus for the Production of Three-dimensional in form Objects by Stereolithography." Aprecia Pharmaceuticals launched the first 3D printed orodispersible capsule for seizure treatment, Levetiracetam, in 2015. The medication in question can treat spasms (Tonic-clonic and partial-onset) for both adults and children. The National University of Singapore (NUS) has developed software that generates customized pharmaceuticals based on the patient's needs. The computer program settings can be modified based on the total number of tablets required. Pills can be created at-site for patients or on large-scale production for pharmaceutical companies. In the 1980s, numerous additive manufacturing methods have been studied and developed, like Carl Deckard's Selective Laser Sintering (SLS), a method known as Direct Metal Laser Sintering (DMLS) from the German company EOS GmbH, and S. Scott Crump's Fused Deposition Modelling. Crump later co-founded Strategy's with his wife Lisa, and the company has remained an expert in the manufacturing of FDM printers. 3D printing has already made significant effects on several crucial areas of craniomaxillofacial surgery, orthopedic surgery, and beyond.[2]

Techniques of 3D Printing

Depending on the application specifications, the following 3D Printing technologies might be applied:

Selective laser sintering (SLS) -It is a rapid prototype development technology that shifts 3D CAD data into genuine parts in only a couple of hours. It is an AM technique that combines powdered nylon 11, nylon 12, and PEEK materials. The parts established are lightweight, extremely resilient, heat resistant, and able to withstand chemicals. The low-cost production portions are manufactured effortlessly without expensive tools required. First, the 3D CAD data has been separated into thin cross-sections referred layers. After partitioning the data, it is transmitted to the SLS AM equipment. The machine methods the first layer of powdered material, that gets afterwards spreading all throughout the cross-section by a leveling roller utilizing a laser beam. Following the completion of the first the layers, the powder bed has been created for the subsequent covering by dropping it down. Layer by layer deposition proceeds to be carried out till the section of interest has been obtained. [1]

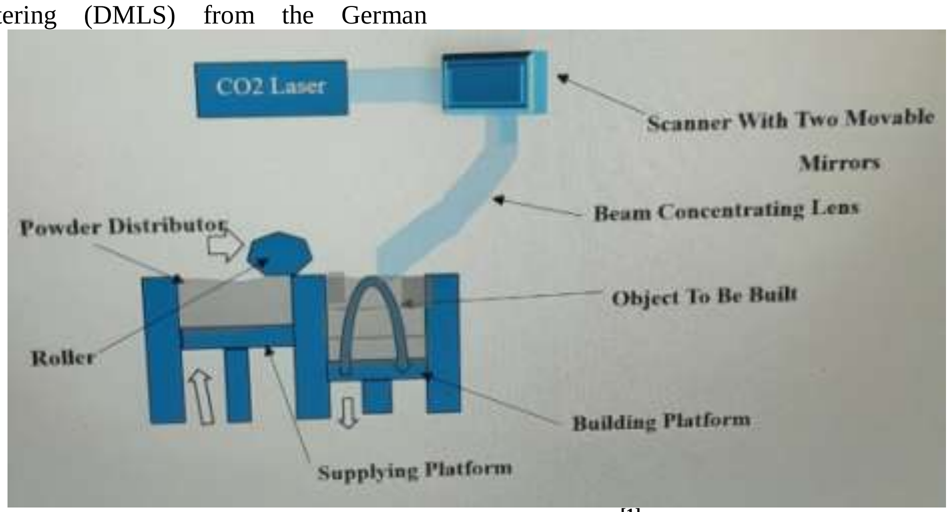

Fig.Selective laser sintering[1]

Fused Deposition Modeling (FDM) -

This innovation is utilized for making tough regular objects. The 3D printer takes industrial-grade thermo-plastic fiber which is softened at that point expelled on a plate to construct a total portion layer by layer utilizing a bottom-up approach. The impediment of this method is the prerequisite of a tall preparing temperature for creating dynamic thermo-labile compounds. [1]

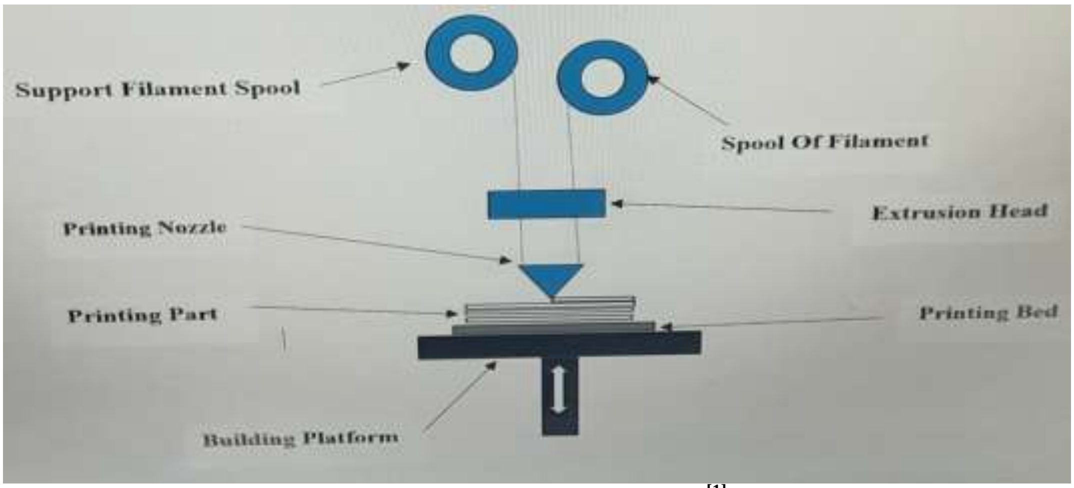

Fig. Fused Deposition Modeling[1]

Stereolithography (SLA) OR Stereolithography OR SLA –

It is the earliest rapid prototyping technology, therefore it is utilized to create idea models or as a master pattern for molding procedures. CAD data is first divided into cross-sections or layers before being sent to a SLA AM system that contains a vat of UV-curable photopolymer. The UV laser is utilized to create the layer with X and Y scanning mirrors. When the laser strikes the cross-section of the resin, the liquid material hardens on contact. When a layer is finished, the build platform is indexed down so that the next layer can be added. Using a bottom-up technique, the layers are stacked one on top of the other.Stereolithography (SLA), a 3D printing technique, is very rapid and highly accurate and produces finished products of uniform quality.Complex designs/shapes can be fabricated through SLA using the photopolymerization principle.[1] [3]

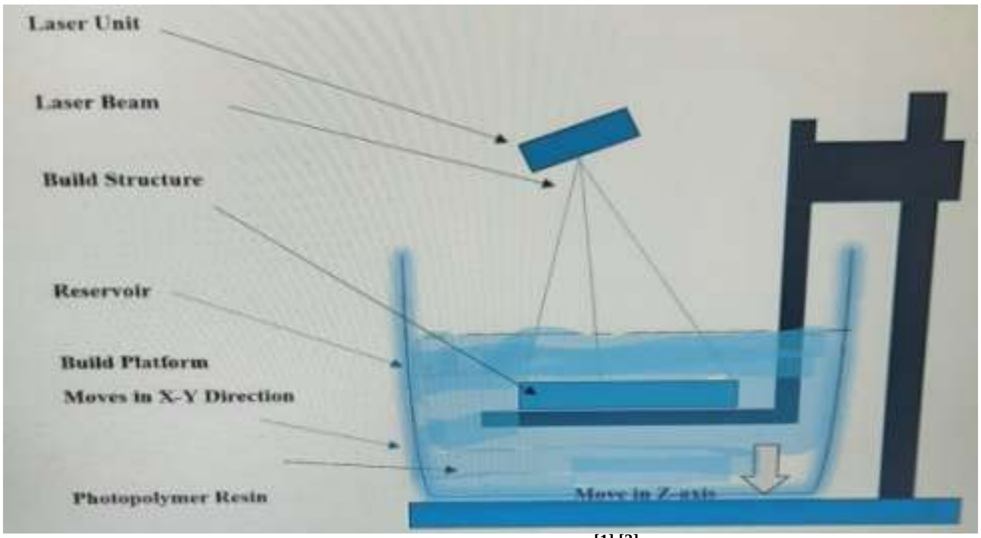

Fig. Stereolithography[1] [3]

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Semi solid extrusion :

Semi-solid extrusion (SSE) is a subset of material extrusion 3D printing that consists of the subsequent deposition of layers of gel or paste in order to generate an object of a particular measurement and shape. Comparing to other extrusion-based technologies, SSE 3D printing leverages low printing temperatures, making it suitable for medication administration and medical purposes, and the use of syringes that are reusable provides benefits for attaining significant safety requirements associated with pharmaceutical use.[4] [5]

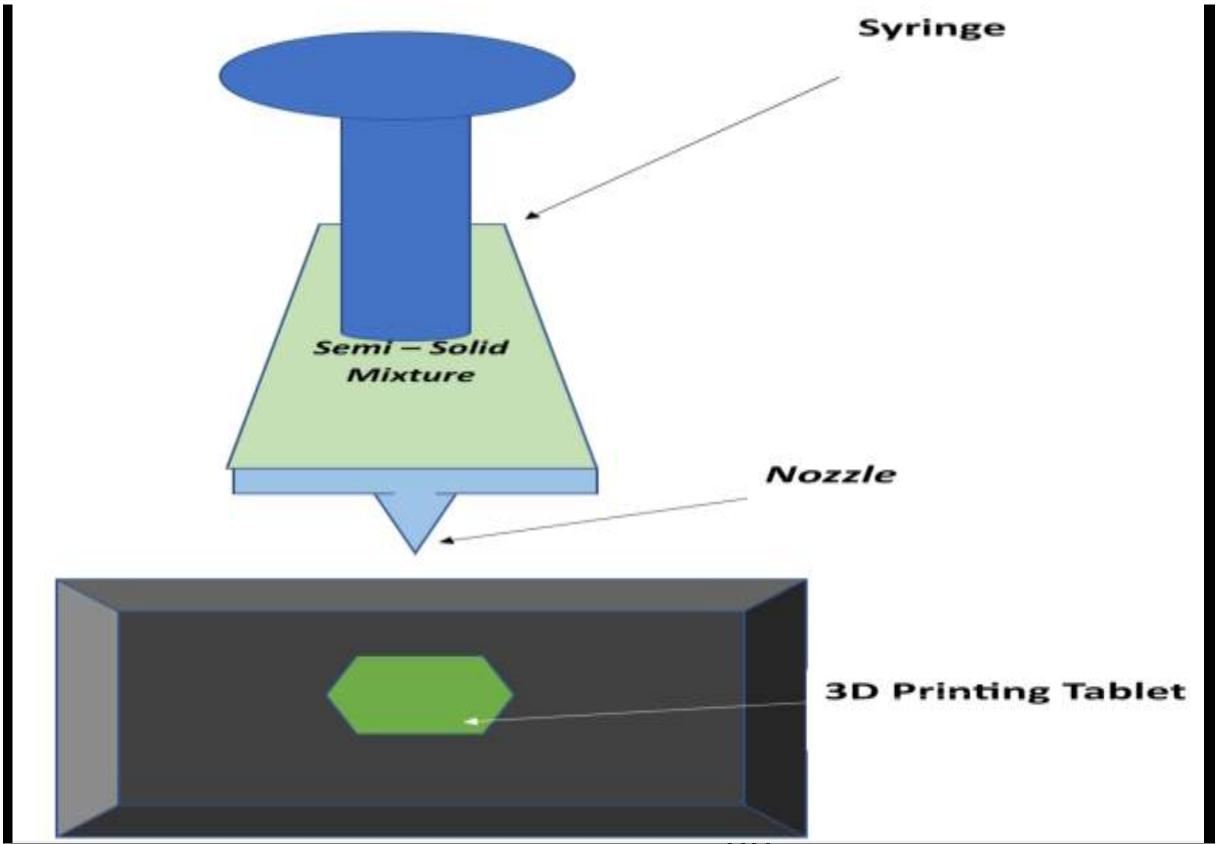

Fig. Semi solid extrusion[4] [5]

Thermal Inkjet (TIJ) Printing –

It is a non-contact conduct that use electromagnetic, thermal energy, or piezoelectric devices to deposit microscopic droplets of ink onto substrates determined by computerized instructions. In this printer, resistors produce heat, and ink evaporates in order to create a bubble. As the bubble increases, ink is released through a tip of the nozzle on the material being printed. In short, the mechanism of inkjet printing comprises three main phases: (1) ink ejection and droplet development, (2) liquid-solid interaction at once droplets have been placed on the substrate's surface, and (3) dripping of technologies. This method is additionally referred to as bubble inkjet printing since the droplets of polymer are released via bubble nucleation. [1] [6]

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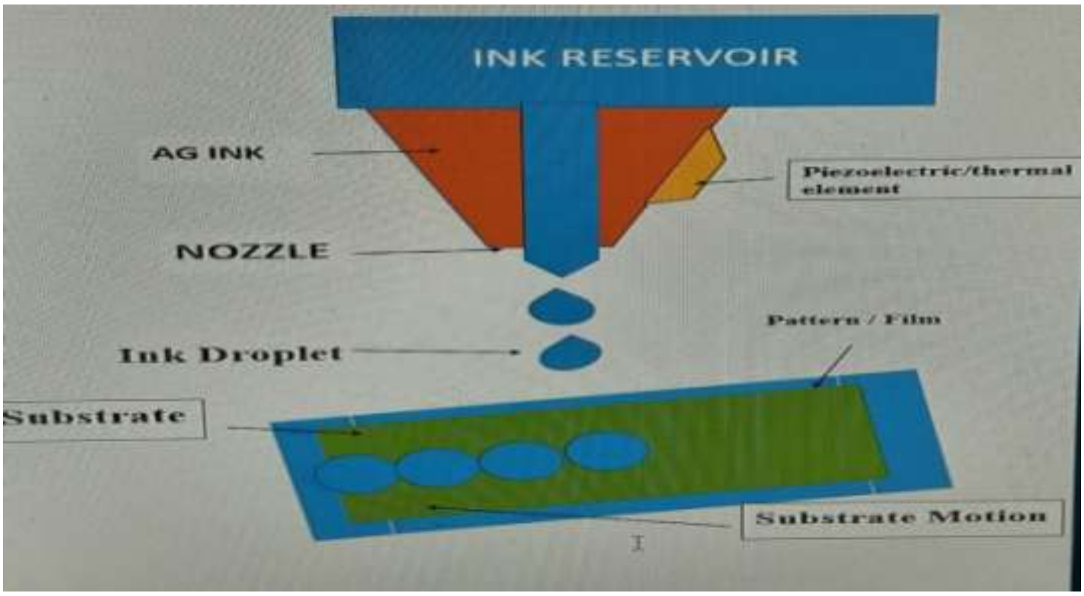

Fig. **Thermal Inkjet Printing [1] [6]**

Binder jetting 3D Printing –

This method of conditioning incorporates a wide range of particle materials, comprising sand, polymer compounds, and freely determined powder materials. The most important requirement is the CAD information associated with the part. The process gets started with a recorder submitting an application looseparticlematerials to the building platform, subsequently followed by the printhead carefully distributing the binder to the areas where future parts need to be produced, consequently connecting the layers.Each layer is printed one by one, up until the desired structure is accomplished.BJ3DP machines are capable of producing prototypes with substance characteristics and finishes on the surfaces equivalent to those accomplished with conventional powder metallurgy. Various powdered materials have been 3D printed, but the most prevalent issue during BJ3DP involves setting up printing and post-processing processes that maximize part performance. To gain a deeper understanding of the microstructural evolution and characteristics of binder jetted parts, an in-depth investigation of the physical processes associated with 3D printing, in addition to the scientific foundations of densification complying with sintering and post-heat treatment actions. [1] [7]

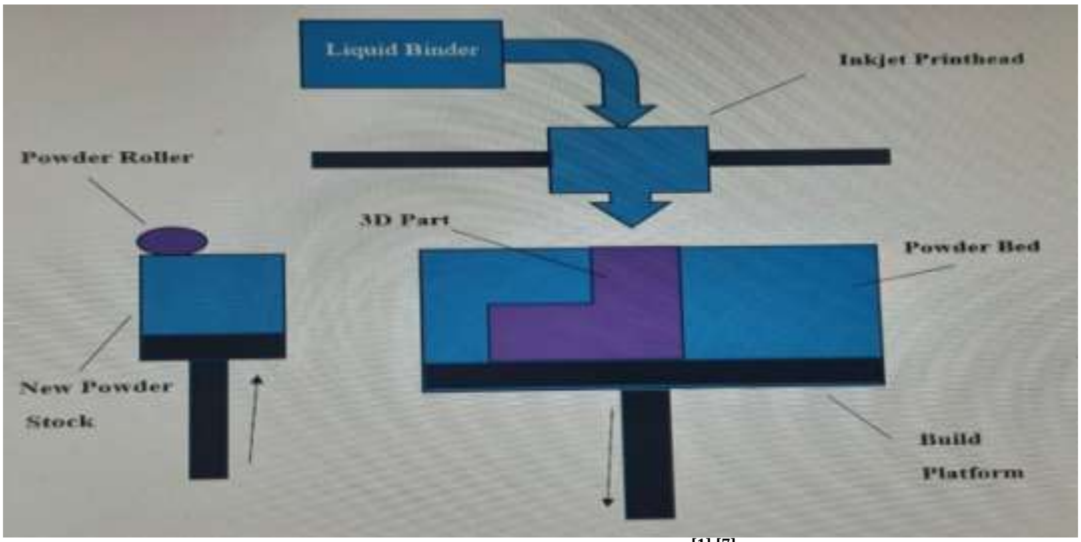

Fig. Binder jetting 3D Printing[1] [7]

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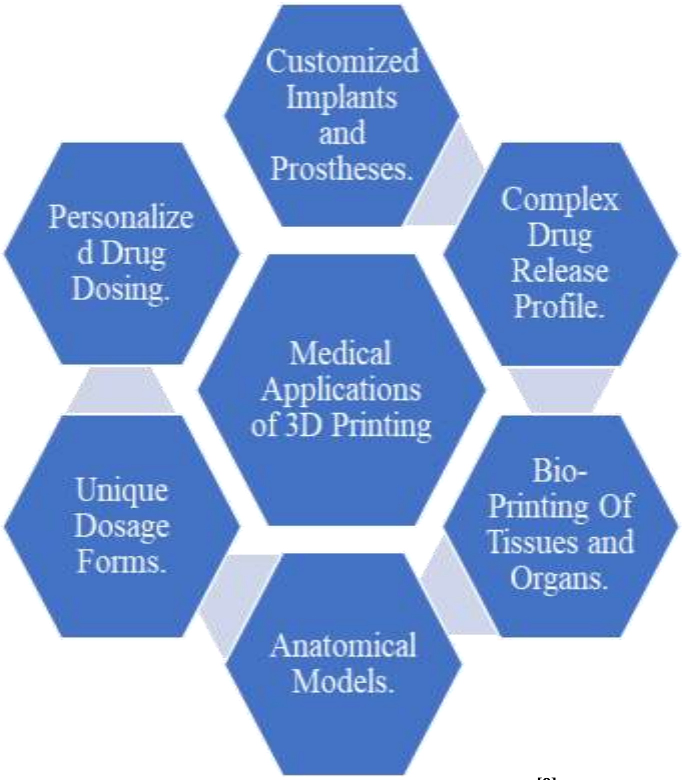
Medical Application



Medical Applications of 3D Printing – [8]

Bio-printing of Tissues and Organs –

One critical medical problem is organ and tissue dysfunction due to accidents, birth defects, aging, etc. And the current solution to this problem is organ transplantation from deceased or living donors. But only a lucky few get organs and the rest die for lack of a donor. In addition, organ transplant procedures are so expensive that ordinary people cannot afford them. Another problem with organ transplant surgery is that it is difficult to find matching tissue donors.

Admittedly, organ printing is still in its infancy, but several studies have shown proof of concept. Scientists have used 3D printers to build an artificial ear, cartilage and bone, and a heart valve. [8]

Unique Dosage Form –

Infinite dosage forms can be created with 3D printing. Inkjet-based 3D printing and inkjet-based 3D printing are two of the most important printing technologies used in the pharmaceutical industry. Microcapsules, antibiotic-printed micropatterns, mesoporous bioactive glass scaffolds, nanosuspensions and synthetic extracellular matrices based on hyaluronan are some of the new 3D-printed dosage forms. [8]

Personalized Drug Dosing –

The production of a completely new dosage form is another essential potential of 3D printing, for example in the production of pills containing a mixture of more than one pharmaceutical active ingredient or dosed as multi-reservoir pressed tablets. Thus, patients suffering from more than one disease can receive their preparation in one multi-dose form at the health point itself, ensuring an individual and precise dose for the patient with better or better compliance. [8]

Complex Drug Release Profile –

Most conventional compressed dosage forms have a simple drug release profile that is a homogeneous mixture of active ingredients. Instead, 3D-printed dosage forms have a complex drug-release profile that allows the fabrication of complex geometries that are porous and filled with multiple drugs surrounded by release-modulating barrier layers. One example is the printing of a multilayer bone implant with a different drug release profile that alternates between rifampicin and isoniazid in a pulse release mechanism. [8]

Customized Implants & Prostheses –

By using MR, CT scans and X-rays and converting them into .stl 3D printing files, implants and prostheses of any shape can be produced. The first 3D printed titanium mandibular prosthesis was successfully implanted at the BIOMED research center in Belgium. [8]

Anatomical Models For Surgical Preparations –

Knowledge of patient anatomy prior to medical surgery is essential for successful medical procedures due to the individual and complex differences in human anatomy. 3D printed models have helped a lot in this, making them an essential tool in surgical procedures.

One of the most complex structures in the human body is the head, where 3D printed neuroanatomical models are of great help to neurosurgeons. [8]

ADVANTAGES & DISADVANTAGES OF 3D PRINTING

Advantages -

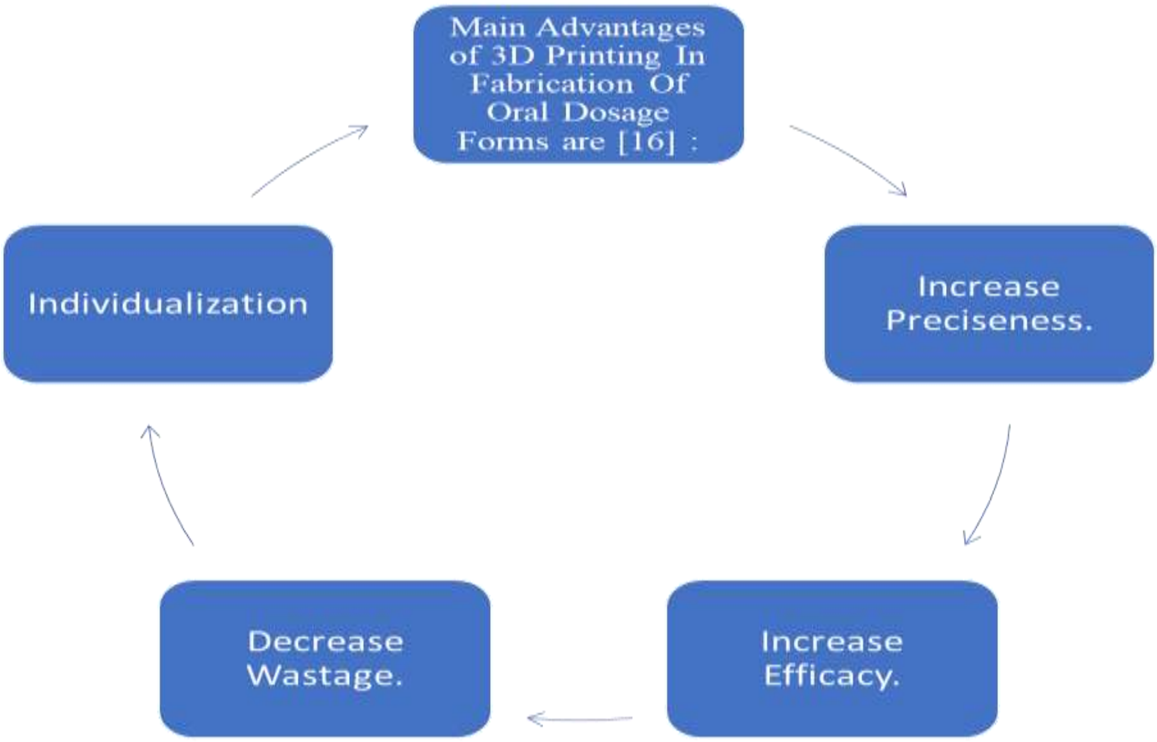
New Formulations For Improved Drug -

New dosage forms for an improved drug. In the traditional method of drug preparation, some tablets are difficult to swallow. But with 3D printing, the pills can be designed according to the patient's preferences. [10]

3D printing techniques have been used to produce a number of pharmaceutical products, such as immediate-release tablets, controlled-release tablets, dispersible films, micro-needles, implants and skin patches. [11] [12]

Modern Medical Care -

Through 3D printing of human organs such as livers, kidneys and hearts, 3D printing is used in the medical field to help modern medicine and save lives. Some of the greatest technological advances have been made in the healthcare industry, where new uses and advances are constantly being developed. [13]



Environmentally Conscious –

This procedure is essentially environmentally positive and environmentally conscious, because it reduces the amount of necessary material waste. [13]

Quick Prototyping –

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The rapid prototyping phase is accelerated by the ability of 3D printing to produce parts in a few hours. This makes it possible to complete each step faster.

Compared to machine prototypes, 3D printing is cheaper and faster in the production of components, as a part can be made in a few hours. This allows each design change to be completed much faster. [15]

Versatile Design –

3D printing can produce and produce more complex models than traditional manufacturing methods. The design limitations of more traditional technologies are no longer a concern when using 3D printing. [15]

Precision / Personalized Medicines –

An important advantage of 3D printing drugs is the ability to adjust the individual dose. Therefore, this method is useful in the treatment of patients with complex diseases that require individual treatment. Warfarin is one drug that requires dose modifications due to its narrow therapeutic index. [16]

DISADVANTAGES -

Safety and Efficiency of 3D Printers –

The traditional way of producing medicines is under strict control by authorized agencies such as the FDA. This assures the company and consumers that the products are made with care.

However, when it comes to 3D printing, the FDA cannot regulate all printing operations. Thus, the decisiveness of product development can be questionable. Additionally, 3D printing still has the potential for faulty 3D printers and unnecessary printing errors. [10]

Intellectual Property Rights Problems –

The availability of reproductions of products produced with 3D printing technology is easy, which can raise questions about intellectual property rights. This can hinder the benefit the organization is seeking. [17]

Limitations Of Size –

One of the disadvantages of 3D printing technology is the size limitation. It is still not possible to make very large structures when building with 3D printers. [17]

Cyber Risk –

The rapid increase in reproducing fake pills is one of the greatest concerns with 3D printing. [10]

Not Eco-friendly / Not a green Choice –

This is not a green (environmental) choice. The use of plastic and energy in 3D printing technology is very extensive. Therefore, 3D printing can only be a small part of the solution if a medical device manufacturer wants to reduce overall energy use or emissions. [15]

Uses of 3D Printing -

GENERAL USES –

In Aerospace –

3D printing is used throughout the space (and aerospace) industry for its ability to create lightweight but geometrically complex parts like the Bliss. Instead of building a part from multiple components, 3D printing allows you to create an object as a single unit, reducing lead times and material waste.[18]

In Automotive –

The automotive industry has embraced 3D printing for its weight and cost reduction. It also enables rapid prototyping of new or custom parts for trial or small-scale production. For example, if a certain part is no longer available, it can be done as a small custom job, including parts manufacturing. Alternatively, products or furniture can be printed overnight, ready for testing before larger production. [18]

In Robotics –

The speed of production, freedom of design and ease of design customization make 3D printing ideal for the robotics industry. This includes work to create specialized exoskeletons and dexterous robots that improve agility and efficiency. [18]

3D Printing Services –

TWI has one of the most advanced 3D printing services, including selective laser casting, laser coating, wire and arc additive manufacturing, wire and electron beam additive manufacturing, small-scale EB powder bed fusion prototyping and more. [18]

In Rails –

The railway industry has found several applications for 3D printing, including the creation of custom parts such as driver armrests and train

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switch box covers. Custom work is just one application for the railroad industry, which has also used the process to repair worn rails. [18]

Pharmaceutical Uses

Modified Drug Delivery System –

Compared to traditional manufacturing techniques, 3D printing offers the flexibility to design complex 3D drug structures, customize drug doses and combinations, and rapidly manufacture and prototype. [19]

Personalized Medicine –

Compared to traditional drug manufacturing processes, 3D printing technology has significant advantages in the manufacture of personalized drugs, which enables easy production of products with complex structures or drug-releasing behavior and rapid production of small batches of drugs. [20]

Designing Medical Devices –

To fulfill the purpose, medical devices must meet several requirements: They must have a perfect balance between size and weight. They must conform to certain shapes of the human body. They must be functional and pass special durability tests. Manufacturing medical devices to meet these criteria has traditionally required a lot of time. An alternative found by medical device manufacturers was stereolithography, a process in which a computer-controlled moving laser beam builds the required structure layer by layer. Thus, a prototype of the inhaler with the necessary fasteners and jigs was created using 3D printing. The goal is: Reduce production from one week to two days. Reduce costs by 90%. [21]

Creating Prostheses –

While simple prostheses are available in predefined sizes, custom bionic prostheses cost thousands of dollars. This situation affects many children who outgrow their prostheses and need custom replacements made by a handful of manufacturers Lyman Connor and Eduardo Salcedo created Lyman Mano-matic Prosthesis in 2016 to provide bionic prostheses to those who need them. and cannot afford them. Prosthetic designers around the world can use 3D printing to overcome the financial barriers and time constraints of this process. The cost of this production method is significantly lower than traditional methods, and prostheses can be completed in about two weeks, making 3D printing a viable solution for custom bionic devices that mimic the movements and grips of a human limb. [21]

3D Digital Dentistry –

In the dental field, 3D printing is used in dentistry. Prostheses, surgical guides, bridge models, and above all, the production of glass aligners – invisible teeth straighteners.

Metal braces are invisible and can be removed when the user needs to brush their teeth. Teeth or eat. The traditional method of manufacturing cleaning machines is a combination of manual and grinding processes, which require time and effort. 3D printing technology speeds up the process, as custom molds for clear aligners can be made directly from digital scans of patients.

Looking for cost-effective solutions, a dental company developed a simple process to make molds for clear aligners. Aligners: Customers take impressions of their teeth through home printing or intraoral scanning at a specialized center.

The Impressions and scans are reviewed by a dentist who creates a treatment plan.

The company then ships 3D-printed aligners to customers.

This makes 3D printing cost-effective to make clear aligners because installation and tools are not expensive, and their customization proves to be simple and easy. [21]

Streamlining Drug Administration –

3D printing can also facilitate drug administration with 3D printed pills. A polypill is a concept designed for patients with multiple illnesses that contains five different drug sections and two different release profiles.

Patients with multiple illnesses often take their medications at different times of the day and this can be confusing. Schedule This 3D printed pill addresses both drug dosage and potential interactions between drugs treating different conditions, eliminating the need for such time and careful monitoring.

Having one custom pill to treat multiple conditions has several advantages:

Respect of medicines for the prescribed treatment.
Personalized medicines or combinations of drugs.
Lower production costs because we can treat several diseases at the same time.
Developing countries have even better affordable and effective medicines. [21]

Improving Surgical Instruments –
Custom 3D-printed surgical instruments, such as knives, forceps or clamps, help surgeons work better in the OR, shorten operating time and promote better surgical outcomes for patients. [21]

Customized Surgery –
With the decrease in the price of 3D printers and the increasing availability of medical CAD/CAM software, more and more hospitals are creating in-house 3D printed anatomical models. The process consists of several steps:
MRI and CT scans are processed in a step called segmentation.
Each organ and body part type is modeled.
The models are translated into STL file formats, organized for printing, and sent to a 3D printer.
Using 3D-printed anatomical models, surgeons can effectively plan operations and create better treatment solutions, shorten operating times, and improve research and training of medical students. [21]

3D Printed Implants –
Metal 3D printing enables medical device designers to produce implants that work better, fit better and last longer in the knee, spine, skull or pelvis. Electron Beam Melting (EBM) is a technology that melts metal powder layer by layer. With an electron beam, resulting in very precise parts. These orthopedic implants provide spongy structures that mimic normal bone tissue, resulting in a higher rate of osseointegration – the ingrowth of bone into metal Implants. [21]

ARTIFICIAL INTELLIGENCE (AI) & 3D PRINTING CORRELATION IN PHARMACEUTICAL INDUSTRY

AI algorithms have the potential to improve the 3D printing process in a number of different ways. For example, they can support the design process by making design more efficient, reducing material waste and eliminating the need for support structures. AI algorithms can also improve the production process by adjusting the printing process, monitoring temperature and humidity and making real-time adjustments to conditions. On the other hand, 3D printing can be used to create components for artificial intelligence systems such as sensors, actuators and robots. These components can be tailored to unique needs and requirements, improving the overall functionality of the AI system.

Combining AI and 3D printing can significantly improve the overall production process, making it faster, more efficient and more effective. More precise. It also has the potential to create new business models and product offerings, opening up new markets and revenue streams for companies.

Healthcare is one area where artificial intelligence and 3D printing are being used. Medical models, implants and prostheses can be made for each patient, especially with 3D printing technology. AI algorithms can then be used to improve the design and functionality of these goods. [22]

Future Prospective

3D printing can transform the practice of clinical pharmacy. This could change conventional means of mass production of pharmaceutical products to on-demand production of small batches of highly flexible and individualized dosage forms. This technology benefits patients, pharmacies and the pharmaceutical industry alike, offering unique benefits such as making treatment safer and more effective. Healthcare professionals, including pharmacists, doctors and nurses, are critical to the integration of this technology and help advise academics, the pharmaceutical industry and biotech companies on strategies to innovate the industry with 3D printing. [23]

The use of 3D printing in medical applications is promising for the future; however, despite scientific knowledge, there are significant barriers to successful implementation. The research aims to successfully print 3D organs for transplantation, and breakthroughs that allow autologous 3D printed organs using the patient's own cells may soon occur. However, 3D printing of the complex cytoarchitecture of organs remains challenging. In addition, 3D printing could be used more as a teaching tool. In pharmacology, 3D printed patient-specific medical research is expected to expand, and companies such as Curifylabs have developed automated digital technology (Curify MiniLab) for 3D printing drugs; However, it is not known if there are multiple dosage forms in one tablet. In addition to improving the efficiency and speed of 3D printing, a logical direction for pharmaceutical companies would be to explore modifying existing products to facilitate 3D printing and expand the range of 3D printable materials. [24]

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II. RESULTS & DISCUSSION -

3D printing in healthcare improves patient care. This innovative technology tailors medical solutions, including devices, implants and treatments, to individual patients. 3D printing makes it possible to create complex, highly functional medical devices with complex geometries that were previously unmanufacturable. In addition, pharmaceutical innovations in 3D printing offer unique dosage forms and formulations that could revolutionize personalized drug delivery. Patients benefit from more effective medicines with fewer side effects.Rapid prototyping accelerates the development of cutting-edge healthcare solutions and ensures faster access to advanced treatments and devices. Care manufacturing enabled by 3D printing improves surgical precision and reduces waiting times for medical procedures, ensuring fast and efficient patient care.[37]

Outcomes –

The impact of 3D printing goes far beyond manufacturing and design, touching different sectors and opening up innovative solutions. Here's a closer look at how 3D printing is making waves in the industries:

- Health: Personalized medical solutions.
- Automotive: Accelerating innovation.
- Space: Efficient components.
- Architecture and construction: Sustainable construction.
- Consumer products: Custom products.
- Education and research: Hands-on learning.

In healthcare, 3D printing has emerged as a game changer. This enables the creation of patient-specific medical solutions, from customized implants to prosthetics tailored to individual needs.Surgeons and medical professionals can now design and manufacture implants that perfectly fit patients, reducing the risk of complications and improving overall patient outcomes. . In addition, 3D bio-printing is rapidly developing and offers the opportunity to revolutionize organ transplantation with the ability to print functional tissues and organs.[38]

III. CONCLUSION –

3D printing is an amazing and exciting tool and has had a major impact on various industries over the past decade. Improving traditional techniques and research with the introduction of newer and more efficient additive manufacturing methods can increase the use of this valuable tool.

Although 3D printing of fine details was initially difficult compared to other manufacturing techniques, technology such as SLS has commercialized layer. Printer's heights up to .05 mm and produce parts of .15 mm and developing. The commercialization of 3D printers has increased the speed of improvement and improved the user experience and ease of use. Additionally, it requires fewer problems, making it more accessible to individuals.

Many medical fields have used 3D printing in their practice, and applications continue to appear in the literature. The practicality of physical 3D models has aided education, surgical planning and research, and led to improvements in medical devices. It is not difficult to imagine medical device companies using large hospital 3D printing centers as internal tools to produce custom products, outsource design, and develop new custom manufacturing chains. Perhaps in the future ordering a custom implant would be as easy as sending a 3D file to a printer to print.

Technology is not perfect. It requires experience in troubleshooting software and hardware issues. In addition, the increased printing time means that printing errors are harmful and time consuming. Despite the wide range of printable materials, many other materials cannot be used in 3D printing; in addition, special preparations are required before the material can be used, and 3D printing of very large objects (i.e. hospital beds) is not currently a practical production method. It's exciting to see the future of 3D printing and innovation in technology and medical applications, and as some experts predict, the industry is just getting started. [24]

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