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The Emerging Trends of 3d Printing Techniques in Pharma Sector

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Abstract:- Technology involving 3-dimensional printing has begun to revolutionize several fields, including pharmacy. In pharmacy, it offers a reliable avenue for precision medicine, dosage forms and drug delivery systems. The creation of complex drug structures with precise control over composition, shape and release kinetics, catering to individual patient needs has been possible with the intervention of this method. One significant utilization in pharmacy is the customization of dosage forms. Traditional manufacturing methods often struggle to produce tailored medications for patients with unique requirements, such as paediatric or geriatric populations. With 3D printing, pharmacists can create personalized medication with appropriate dosages, structures, and release kinetics, improving patient adherence and beneficial results. Moreover, sophisticated medication delivery systems may be created thanks to 3D printing. For instance, multi-layered tablets can be designed to release multiple drugs at different rates, optimizing treatment regimens for conditions requiring combination therapies. Furthermore, intricate structures like porous scaffolds or micro needle arrays can facilitate targeted drug delivery, enhancing bioavailability and minimizing side effects. Additionally, 3D printing facilitates the rapid prototyping of pharmaceutical formulations, accelerating the drug development process. Researchers can efficiently iterate through various designs, optimizing formulations for efficacy, stability and manufacturability. Despite its promise, challenges remain in integrating 3D printing into mainstream pharmacy practice, including regulatory hurdles, material selection and scalability issues. However, ongoing advancements in technology and collaborations between academia, industry and regulatory agencies are driving progress in overcoming these barriers. In conclusion, 3D printing technology holds immense potential to transform pharmacy by enabling personalized medicine, new dosage formulations and cutting-edge medication delivery technologies. As research and development in this field continue, the prospect of tailored pharmaceuticals tailored to individual patient needs becomes increasingly attainable.

Keywords:- *3D Printing, Precision Medicine, Release Kinetics, Porous Scaffolds.*

I. INTRODUCTION

Drug delivery encompasses various methods, mechanisms, advancements, and formulations designed to transport a pharmaceutical substance within the body to effectively attain its intended curative outcome. The development of medication administration has progressed significantly, transitioning from conventional immediate-release oral medications to more precise targeted-release delivery systems [1]. The process of three-dimensional printing is an innovative technique used for rapid prototyping. It involves the creation of solid objects by depositing multiple layers in a sequential manner [1], [3]. 3DP has the ability to manufacture 3D items by merging various layers in a specific order regulated by computer-aided design software. The 3D printed drug delivery system allows for personalized treatment through multi-drug therapy and flexible dosing schedules. This innovative technology eliminates the inconsistencies often found in traditional bulk manufacturing processes. The development of multiple drug delivery methods, including oral controlled release systems, implants, modified release dosage forms, pills, microchips, multi-layered tablets with linear release kinetics, and immediate-release tablets, is further aided by the use of this technology. Moreover, this method works well with a wide range of active pharmaceutical components, including peptides, proteins, and medications that are poorly soluble in water. [2]. This technology uses a bottom-up approach in which different materials are piled on top of one another to make the desired 3D object. These materials include wood, alloy, thermoplastic, metals, live cells, and more. Consequently, other names for 3D printing have been coined, including layered manufacturing, additive manufacturing, computer automated manufacturing, rapid prototyping, and solid freeform technology. The many uses of 3DP in the medical field-such as organ printing, tissue design, manufacturing biomedical equipment, diagnostics, and drug and delivery system design- benefit the industry tremendously. Computed tomography (CT) scans and magnetic resonance imaging (MRI) are two methods that can be used to produce data for the creation of intricate anatomical and medicinal structures that are customized to the needs of the patient. Additionally, this technique can be used to generate new organs that duplicate the functions of the original organs, as well as replace or repair damaged organs like the kidney or heart [3].

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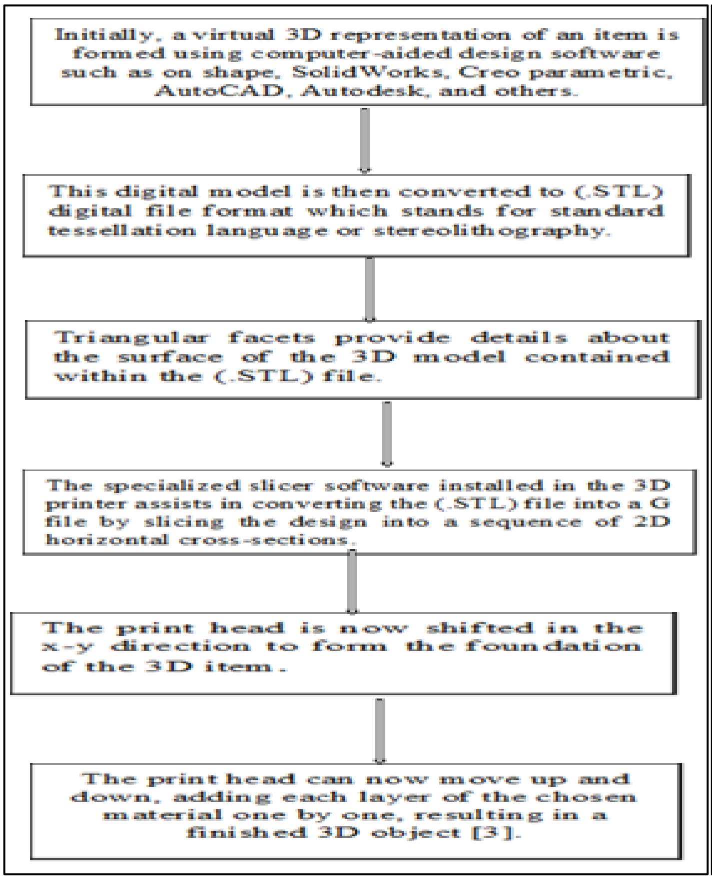
The utilization of this technology has greatly revolutionized the pharmaceutical sector and brought us closer to the age of customized medicine. Individual differences in drugs responses, even at the same dosage, emphasize the significance of individualized therapy. Customizing medicine to meet each patient's needs might lower the possibility of side effects. This strategy can improve patient satisfaction and adherence. Developing suitable dose forms for certain groups, such as paediatric, geriatric, or dysphagic patients, is another aspect of personalized medicine that guarantees efficient pharmaceutical use [4], [5].

- Printing Procedure: The following flow chart depicts the 3D printing procedure

II. TYPES OF THREE-DIMENSIONAL PRINTING TECHNOLOGY

A. Inkjet Printing

Powder is used in 3D printing to create solid dosage forms by spraying active ingredients and ink in varying droplet sizes on a powder substrate. The research investigates the latest developments in inkjet printing technologies, specifically highlighting the advancements in piezoelectric inkjet printing. It evaluates different voltage waveforms used in piezo-driven inkjet printheads and addresses the issues related to printing quality and stability. Additionally, it delves into the diverse utilisation of inkjet printing in textiles, displays, and wearable devices, providing valuable insights and guidance for industry experts [7], [8], [9].



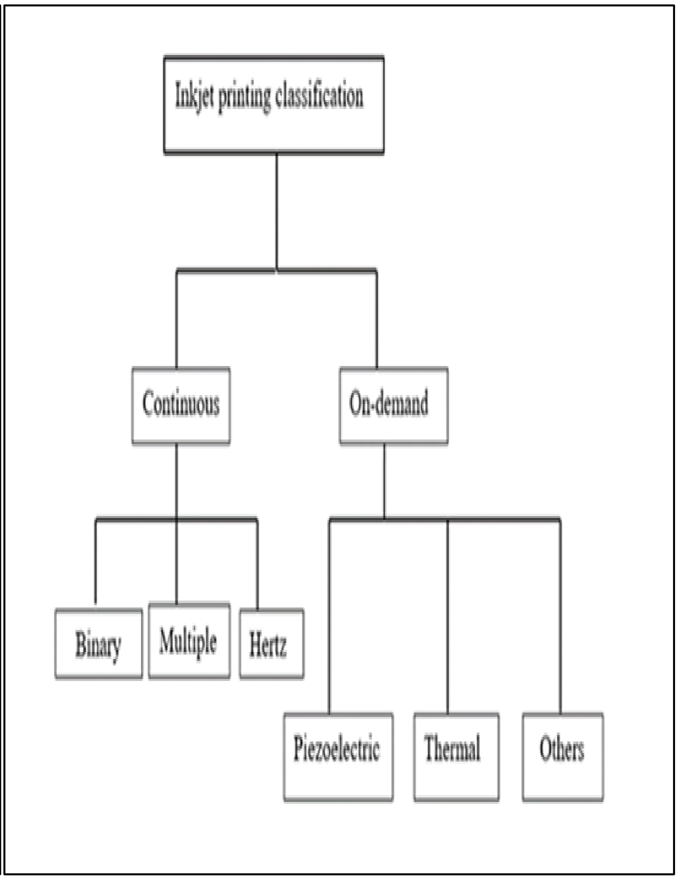


Fig 1: Inkjet Printing Classification

B. Fused Deposition Modelling (FDM)

First, the polymer is selected, melted, and then forced through a heated nozzle. After that, layers of the polymer are placed. The polymer is then deposited layer by layer along all three axes (x-y-z), solidifying into the precise shape designed by computer models. Various forms such as implants and zero-order release tablets containing polymer can be produced using this technique.

Fused Deposition Modelling is a widely used 3D printing technique renowned for its simplicity and cost-effectiveness. This method functions by extruding layers of melted plastic filament based on digital designs. Operating FDM printers requires knowledge of mechanics, software and materials. Adhering to industry standards ensures consistency, while the availability of various filaments offers versatility. Post-processing treatments can further enhance the quality of prints. Despite its advantages such as accessibility and rapid prototyping, FDM does have limitations, particularly in terms of resolution. Nevertheless, its applications are diverse, spanning across biomedicine, construction, automotive, aerospace, and even the response to COVID-19. Looking ahead, future prospects for FDM include advancements in materials and integration with other technologies to expand its capabilities [3], [10], [11], [12].

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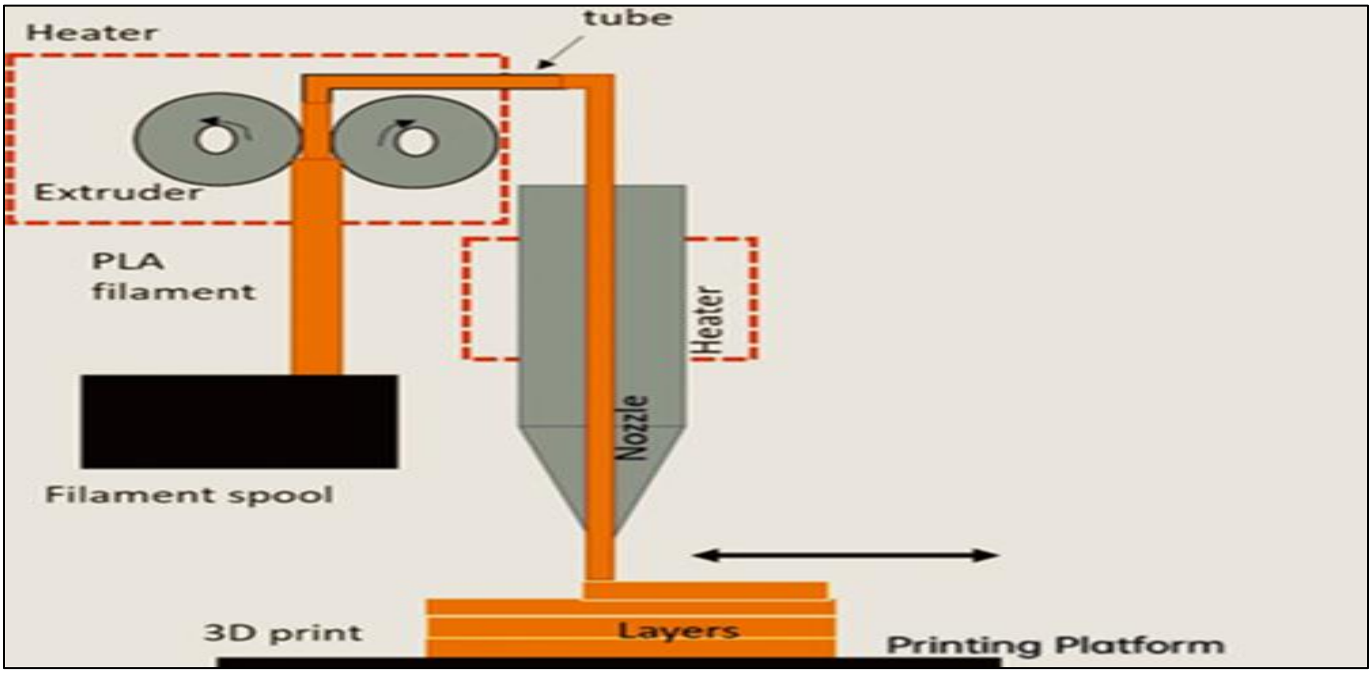

Fig 2: Fused Deposition Modelling

C. Stereolithography

Stereolithography was the to begin with 3D printing prepare made and, concurring to Abreu (2015). It is the most broadly utilized sort of added substance make. By implies of the rate of a bright laser, a layer of fluid tar is set. After this step, the stage where the cemented gum layer is found is moved somewhat descending, causing a layer of fluid tar to be included. Once more, the laser sets the gum making a moment layer. This handle is rehashed until the protest is totally built [13], [14].

D. Power Bed Fusion

The Powder Bed Combination strategy includes the utilize of a fine layer of powder to build a plate, whereas a vitality source like a laser or an electron bar is utilized to liquefy the powder in arrangement with the component's plan [6]. This strategy empowers the laser to specifically liquefy powders layer by layer, coming about within the creation of three-dimensional parts. Amid PBF forms, powdered fabric is spread over the already cemented layer, planning it for the following layer whereas ensuring a particular yield instead of a ceaseless one (in spite of the fact that each layer is melded to adjoining layers). A container apportions the powdered fabric, which is then evenly disseminated over the powder bed to set up a stage employing a roller or brush. The ideal thickness of each layer of powder is decided by the method conditions and materials utilized. Particular Laser Sintering, Electron Bar Dissolving, Specific Laser Softening, Coordinate Metal Laser Dissolving and Coordinate Metal Laser Sintering are all varieties of the Powder Bed Combination strategy [15].

E. Selective Laser Sintering

Selective laser sintering is a rapid prototyping technique that allows the creation of complex shapes by combining successive layers of powder material. Solidification of these layers is achieved with CO2/Nitrogen lasers, depending on the desired surface treatment and joining requirements. Various powders can be used in this process, such as thermoplastics, ceramics, glasses, metals and more. When metal powder is used, the method is called direct metal laser sintering (DMLS). SLS printers consist of two chambers with power transferred from the first chamber to the second where the actual fabrication takes place. The powder is heated below its melting point and a levelling roller or roller flattens the powder to form layers. Once the manufacturing process is complete, a finish is required [16].

F. Binder Jetting

The Massachusetts Institute of Technology introduced Inkjet technology, which has now been modified into Binder Jetting. In contrast to conventional techniques that employ lasers for object binding, Binder Jetting makes use of an inkjet to complete the binding procedure. Using 2D printer technology in an inkjet format, this method progressively builds up layers to produce a 3D object. A print head that moves in two directions precisely deposits a liquid binder during the operation. It starts with the production of a 3D drawing, which is then imported into printer software, much like other 3D printing techniques. The powder that will be used is kept in a dispenser to provide a steady supply during printing. The printing head attaches the binder in accordance with the required specifications after applying a sheet of powder that varies in thickness. Electric or fluorescent lamps are used to dry the solvent containing the binder before proceeding to the next layer. A fresh layer of powder is then placed when the powder bed has been lowered. The binder is put in a furnace when the cycle is finished. Depending on the type of binder being used, different temperatures and times are needed for this phase. Before being employed, metal and ceramic components frequently go through extra steps like sintering, in-filtration, heat treatment, or hot iso-static pressing. But many metals and plastic materials can be

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used right away from the printing machine after production; they don't need to be post-processed [13].

G. Vat Photopolymerization

By curing materials like photopolymers and radiation-curable resins in vats, one layer at a time, with methods like stereolithography, digital light processing, and continuous direct light processing, light-induced polymerization is used to generate 2D patterned layers. Depending on how the light source is oriented and where the polymerization takes place, stereolithography can be classified into two configurations. There are two types of approaches: limited and free [13].

III. CHALLENGES

The 3DP technique needs to get beyond a few challenges before it can be extensively applied in the pharmaceutical sector. The incapacity of this technology to generate goods with the required accuracy during the fabrication process' post-processing phase is one of these difficulties. Furthermore, the product's ultimate form frequently calls for a finishing process like polishing. It is necessary to thoroughly examine a number of technical and physical aspects of 3D printing, such as printability, viscoelastic qualities, thermal conductivity, and the physicochemical makeup of liquid ink. Moreover, dosage forms made using 3DP techniques typically have greater friability than dosage forms made using conventional manufacturing techniques. In contrast to traditional manufacturing techniques, the range of potential raw materials and colorants accessible for 3DP [2].

The implementation of 3DP technology bears the possibility of causing considerable joblessness among labourers engaged in conventional production techniques. But there is a silver lining in addition to this indisputable fact. The need for qualified workers in fields like automation, computer-aided design, materials engineering, information technology, and mathematics—all crucial for the use of this technology—will result in a large number of employment openings [2].

Due to a lack of rules and restrictions, the widespread use of 3DP technology raises serious concerns about the rise in fake drugs [16]. These fake drugs are usually of lower quality and are inexpensively and quickly made again. These medications carry significant health concerns for users, with the potential to cause damage and develop further issues [17, 18]. The commercial market has various challenges in adopting 3DP, including the pharmacological properties of the finished product and the selection of appropriate binders and excipients [19], [20], [21].

IV. ADVANTAGES OF 3D PRINTING

Pen-based 3D printing, moulding, powder bed fusion, inkjet printing, material jetting, fused deposition modelling (FDM), binder deposition, and photopolymerization are a few of the 3D printing methods available. Recently, there has been an increasing amount of research focused on 3D printing as a means of producing personalized solid oral formulations.

However, the varieties of thermoplastic polymers that can be created by commercially accessible FDM printers are severely limited. Often, pharmaceutical corporations do not approve of these materials, nor are they the best for improving the performance of poorly soluble compounds in dosage forms. This technology is currently the subject of extensive investigation because it holds great promise for the manufacturing of medications. The main challenge this profession faces is the shortage of enough [3].

- Prosthetic devices- The use of 3D printing in prosthetic device manufacturing has changed. The development of 3D printing technology has made it simpler and more efficient to create customized, fitted prosthetic devices. With CAD software, prosthetic devices may be quickly and easily modelled and manufactured in three dimensions. If any defects are discovered in a prosthetic device that was 3D printed, they can easily be rectified in CAD and made again. Therefore, 3D printing prosthetic devices may lead to better patient outcomes, comfort, and pleasure.
- Replacing components- Another application for 3D printing technology is its ability to make replacement parts fast. Shorter lead times and a decrease in the requirement for customers to go to pick up items may therefore be quite advantageous to them. Businesses and consumers may maximize the benefits of their purchases and focus more of their time on more urgent problems with the aid of 3D printing.
- Inserts- The 3D printing of inserts can enable more customized products for patients. Patient outcomes are improved when difficult geometry parts are fabricated quickly. Dental implants, maxillofacial implants, knee replacements, and heart valves are among the inserts that can be 3D printed. Soon, it may be possible to 3D print entire organs, which might greatly improve transplant applicants' chances.
- Pharmaceuticals- Using 3D printing, medications of various sizes and forms may be produced, and the active and inactive components can be distributed spatially throughout the body. Because of this, 3D-printed medications can have unique delivery patterns that are adjusted to meet the requirements of individual patients. Although Aprecia Pharmaceuticals' Spritam®, a levetiracetam, is the only medication to be 3D printed, 3D printing could eventually allow for the on-demand, local production of more medications.
- Emergency organizations- Many people may become homeless for an extended period of time as a result of natural disasters like hurricanes, wildfires, and tornadoes. By producing homes, hospitals, and other structures far more quickly than it would take to build them using conventional methods, 3D printing can assist affected families feel less suffering.

- Food- Food can also be printed using 3D printing. Today, vegetables and meat are already produced in labs using stem cells. One day, 3D printing could help feed the globe by producing meat, vegetables, and fruits on a large scale while requiring less space for farming and raising livestock.
- Increased output- Compared to traditional methods, 3D printing produces goods like prosthetics and implants faster. It also offers advantages like improved resolution, reproducibility, and more dependability and accuracy
- Aviation and Space exploration- As humanity attempts to expand its presence in space and interplanetary habitats, 3D printing can be utilized to build tools, equipment, and complete structures on demand. However, 3D printing may be used on Earth to make complex aeronautical components like airframes and avionics housings. When all is said and done, 3D printing can contribute to lower space flight costs, which will help guarantee a sustainable human presence.
- Personalized Apparel- An enormous amount of garbage is produced by discarded clothing in the fashion business. By making it possible to fabricate personalized apparel, 3D printing can help reduce some of this waste. By giving customers, the option to print apparel according to their measurements and style preferences on demand, businesses can produce more of what they want with less waste.
- Tailored Individual Products- A large number of everyday products is made with the average body type or size in mind. Doors, desks, chairs, clothes, keyboards, and other items are made to be utilized by an average-built person in a specific area. For many who don't fit inside these parameters of "average build," this is challenging and can result in discomfort and handicap. Custom-fitted personal items that increase everyone's ergonomics, comfort and safety can be made possible via 3D printing. 3D printing allows the creation of personal products which improve ergonomics, comfort, and safety for everyone.
- Teaching Resources - By using 3D printing, educational materials that are tactile for pupils can be produced. Learning can be improved by 3D printing objects such as biological replicas or topographical maps. Therefore, the application of 3D printing can stimulate innovation, improve education, and promote teamwork [1], [22], [23].

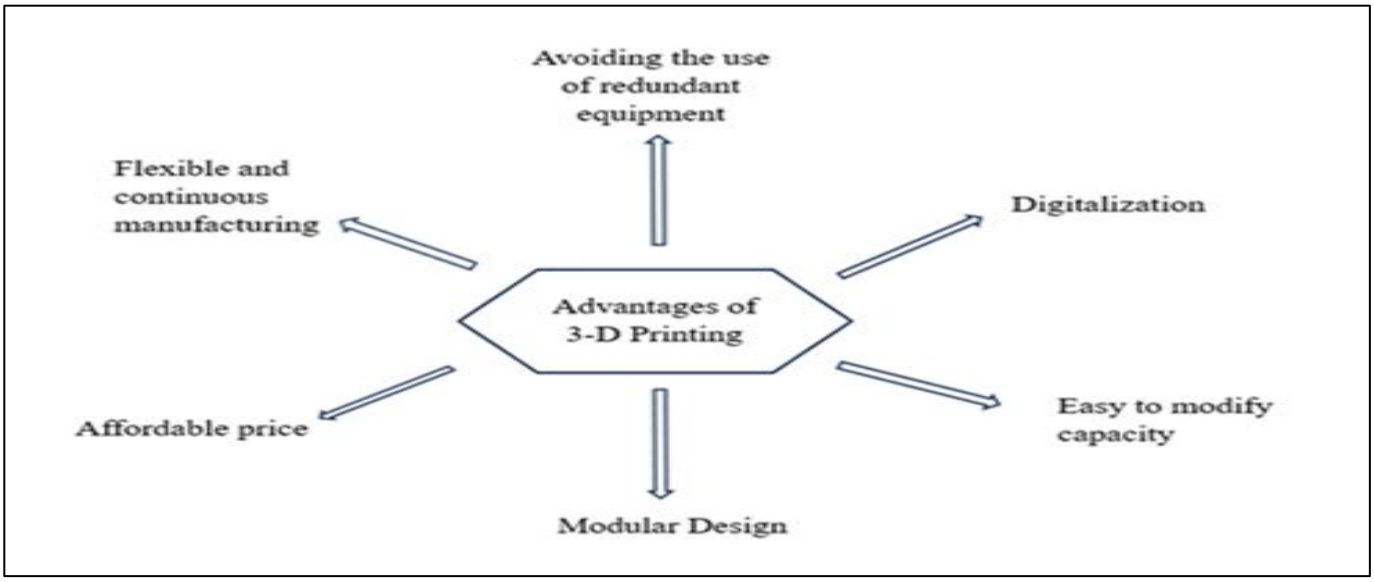

Fig 3: Advantages of 3-D Printing

V. CONCLUSION

3D printing is a method which constructs materials layer by layer through an automated process. The pharmaceutical sector can greatly benefit from the use of this technology, as it enables the development of personalized medicine tailored to individual patients. This innovative technology not only enhances cost efficiency but also accelerates the manufacturing process. A wide range of drug delivery systems will benefit from the quick development and cutting-edge research in 3DP technology, hastening the shift in pharmacy practice toward personalized medicine. Due to the capabilities of 3D printing in creating dosage forms with unique performance characteristics that are challenging to achieve through conventional methods, there is now the opportunity to incorporate these advantages into mass-produced products. In the end, this might improve patient outcomes by increasing medicine efficacy and reducing side effects. Research on 3D printing will continue to advance, opening the door to creative solutions that will help patients and the pharmaceutical sector alike.

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