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ADDITIVE MANUFACTURING: EXPLORING THE IMPACT OF 3D PRINTING ON SOCIETY AND INDUSTRY

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ABSTRACT: 3D printing (a.k.a. fast prototyping or advanced manufacturing process) is estimated to be a highly innovative technology within the healthcare devices industry and pharmaceutical industry. With the use of digitally controlled material deposition straight from a computer-aided design, 3D printing technology can create 3D pharmaceutical items layer by layer. It facilitates the making of dosage forms such as composite products, personalized products, and products made on demand. Pharmacogenetic and pharmacokinetic features, age, weight, comorbidities, and other factors all influence the special needs of each patient, and three-dimensional (3D) printed medications have the potential to revolutionize the pharmaceutical business by providing individualized therapies. These supports provide the choice to alter the drug's efficacy and safety. The capacity to manufacture very little of drugs with customized doses, forms, sizes, and release properties is the primary benefit of 3D printing technology. This method of producing drugs might make the idea of customized medications a reality for bettering patient care. Diverse three-dimensional printing methods have been developed to create innovative solids dosage forms. These technologies include stereolithography, inkjet printing, embedded 3D printing, selective laser sintering, fused deposition modeling, and laminated object manufacture. The varieties, uses, benefits, drawbacks, and difficulties of 3D printing technology are highlighted in this overview.

INTRODUCTION: Due to its numerous uses across several platforms in the healthcare business, 3D printing is generating significant interest along with pharmaceutical and healthcare device production. Although this technology has been around for a while, its authorization of 3-D printed tablets along with additional healthcare supplies has brought it to the public attention.

Fast prototyping, another name for three-dimensional printing, is among the methods used in additive production. This technique turns computer models into three-dimensional structures [1]. A relatively new process known as "three-dimensional printing" (3DP) is used to characterize 3D goods that are created layer by layer on graphic design platforms.

Although it was first created for industrial use, three-dimensional printings gradually increased in popularity as a promising technology. The development of 3D printing technologies in the pharmaceutical sector has completely changed how pharmaceuticals are manufactured and made it possible to convert non-digital medical items into

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digital 3D materials [2, 3, 4]. Numerous uses for three-dimensional printings exist in the pharmaceutical and healthcare industries, including tissue, organ printing, diagnostics, the production of biomedical equipment, medication creation, personalized medicine, and delivery systems [5, 6]. The pharmaceutical industry can employ 3DP methods such as bioprinting, extrusion-based fused deposition modeling (FDM), inkjet-based 3DP, stereolithography (SLA), and selective laser sintering (SLS). Pharmaceutical 3D printing is now receiving a lot of interest as a promising technique that can lower waste costs while improving effectiveness, precision, and individualization. Additionally, the new technology makes it possible to develop innovative consumable dosage forms and healthcare equipment which might be challenging to produce using conventional methods techniques [6, 7, 8]. When dealing with various active component dosage forms, 3D printing technology is crucial since the formulation may be made as a single tablet with a sustained release profile or as several layers printed on it (Horst, 2018). By combining many medications into one Poly pill, adjusting the dose and release profile, and demonstrating its promise in personalized medicine [9]. When compared to conventional dosage forms, this technology offers several benefits, including the ability to achieve precision and accuracy, a reduced manufacturing cost, and a quicker operating system that allows for a greater production rate. However, we may create medications that are customized or patient-specific upon request, allowing us to properly deliver the medication without worrying about any negative pharmacological effects or side effects [10].

Historical Development in the Field of 3D Printing: This concept of three-dimensional printing originated in the early 1970s when Pierre A. L. Ciraud published a description of applying powdered material and then using high-energy beams to solidify each layer. The production of the object in this scenario may involve the usage of a meltable substance, such as metal or plastic. Carl Deckard created a technique for solidifying powdered bed by laser beam known as selective laser sintering (SLS), and Ross Housholder presented an idea for sand binding by using various materials in an early 1980s patent titled "A molding technique for building a 3D article in layers." Stereolithography (SLA) was the first technology developed by Chuck Hull that was made available for purchase. The photopolymerization of the liquid resin by UV light served as the basis for this technique. Scott Crump applied for a patent in the late 1980s for fused deposition modeling (FDM), a method of preparing objects using thermoplastic material. Emanuel Sachs, an MIT scientist, and his colleagues patented "Three-dimensional printing methods" in the 1990s. These techniques involved attaching certain powder patches with a binding substance [11]. The following are the key developments in 3D printing for the pharmaceutical and biomedical industries:

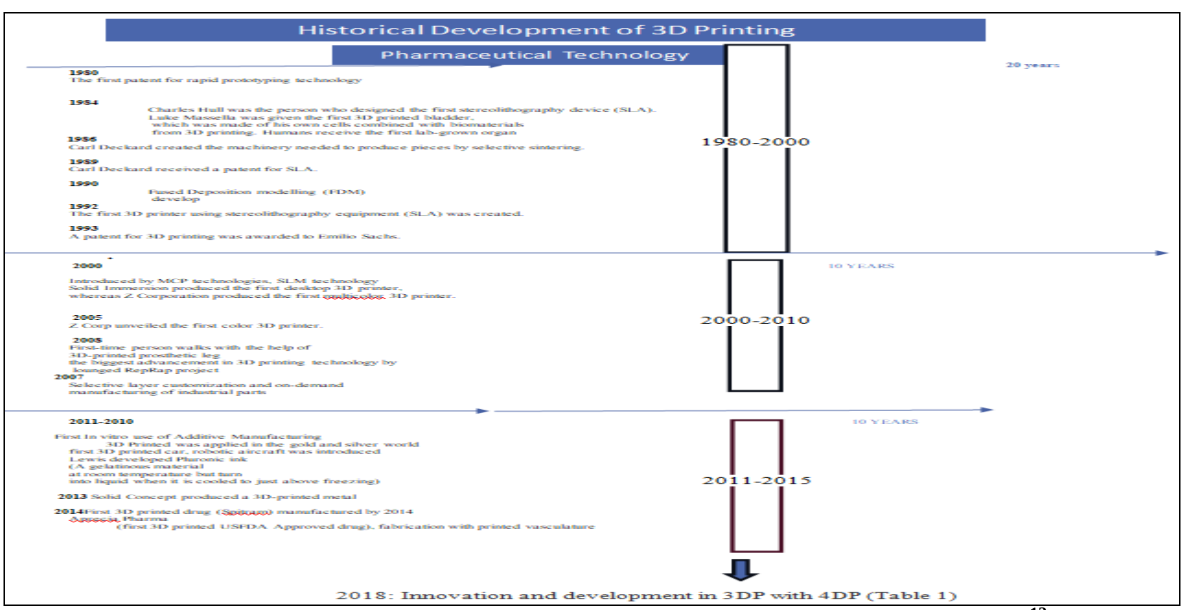


FIG. 1: HISTORICAL DEVELOPMENT IN THE FIELD OF 3D PRINTING [12]

Current Scenario *vs* Demand of 3D Printing: The "one size fits all" approach that underpins medical care today sees the majority of patients receiving the same medications at the same dosages and intervals as other patients [13]. It became apparent that not all therapies can be accommodated by the "one size fits all" idea. Responses have varied when the same active component is given to different people at the same dose. The response may be overstated and linked to unwanted drug reactions (ADRs), or it may be insufficient and have no or poor pharmacological effects. Additional patient issues may arise in each of these scenarios [14]. This results in the development of personalized medicine, which involves creating medications specifically for each patient or for a subset of patients who share comparable genetic, physiological, or pathological characteristics [15]. Aiming to provide the greatest medication at the optimum dose for the patient's specific indication at the appropriate time, with the motto "one size does not fit all," is its mission (Litman, 2019). Precision medicine promises to produce more drugs. These are more cost-effective, safer, and promote patient compliance [16].

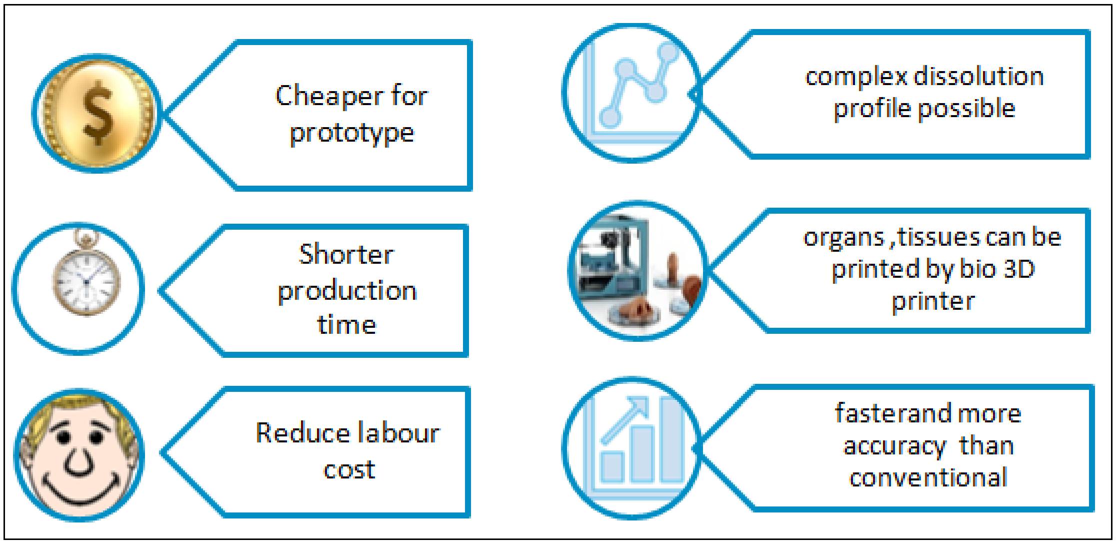


FIG. 2: BENEFITS OF 3D-PRINTING INVENTION

Need and Potential of 3D-Printed Drug Products [17-26]: Conventional oral dosage form dosage forms such as oral dosage form (tablet) are uniform, simple and have more than two years of shelf life. Along with the help of 3D printing technology, it made complex dosage form products and personalized and customized Drug products. Complex products modify the release profile according to the needs of the patient and raise effectiveness and adherence. Drug items that are customized can lessen adverse effects and make treatments easier for elderly and pediatric patients. The skills of emergency medicine are enhanced by on-demand goods, which also align with the marketing strategies of novel medications with restricted stability. In summary, 3D printing has significant promise for innovation and the creation of novel therapeutics, as well as for enhancing adherence to medication, safety, and efficacy in already established therapies. In order to realize these benefits, the FDA supports the advancement of 3D printing technology and the creation of new 3D-printed items. The potential of 3D printing is summarized below:

TABLE 1: POTENTIAL OF 3D PRINTING

Benefit Category	3D printing capabilities	Example uses for drug delivery	Potential medical and economic benefits
Enhanced product design complexities	Printdrugs design, non-mouldable or different in textures. Digitally (computer-aided design)controlling the	Highly porous layer-by-layer drug substance that disintegrates in solid oral forms. To oral substances made approximately zero-order release Different types of excipient gradients enhance the release of drugs.API	Improved adherence to drug medicine. Improved drug effectiveness with improved drug release profile. Reduced side effects by customized drug delivery. New therapies based on

	facility for printing	control on polymorphic form during printing. Complex drug device with a combination of products	multiple combined substances.
Personalisation's	Print makes possible a variety of textures with the same equipment	Helpful Personalized dosing for potent drugs. Children in an age of growing can make personalized medication. Implants filled with drugs and customized to each patient's anatomical shape	Reduced side effects of drug. Helpful to Appropriate doses for children. Minimized complications after implantation due to unique design. Improved pediatric tolerance.
	Variety composite with simpleand portable designs	"Polypills" which mix API and excipient release mechanisms into single dose form. Products with an interior cavity and varying in-fill to regulate the rate of medication release	Less medical costs for old patients. Drug release dosage that is appropriate given the physiology and metabolism of drugs of the patient.
On-demand manufacturing	Rapid printing of prototypes from digital designs – no intermediate processing steps	Printing in emergency need. Printing directly based on the patient's condition. Reducing experimental barriers during drug product development	Increased capacity for surgery and urgent medical needs. shorter duration of time to launch a new medication on the market
	Printing of drugs at the point-of-care	Printed Drugs with limited shelf lives	New drugs easily provided to the market

Difference between Conventional and 3D printing Method: While additive manufacturing doesn't require prior formula or component amount optimization, traditional manufacturing often requires extensive ingredient optimization for batch production. The production process has not changed much over the years, mostly relying on the compression of powders and granules even with advances in technology. In contrast to traditional manufacturing, which requires a lot of time, money, and effort, 3DP is incredibly efficient and economical in all three areas. Customized 3DP technologies also enable the quick creation and development of individualized drug treatments for individual patients, as opposed to a population-centric approach.

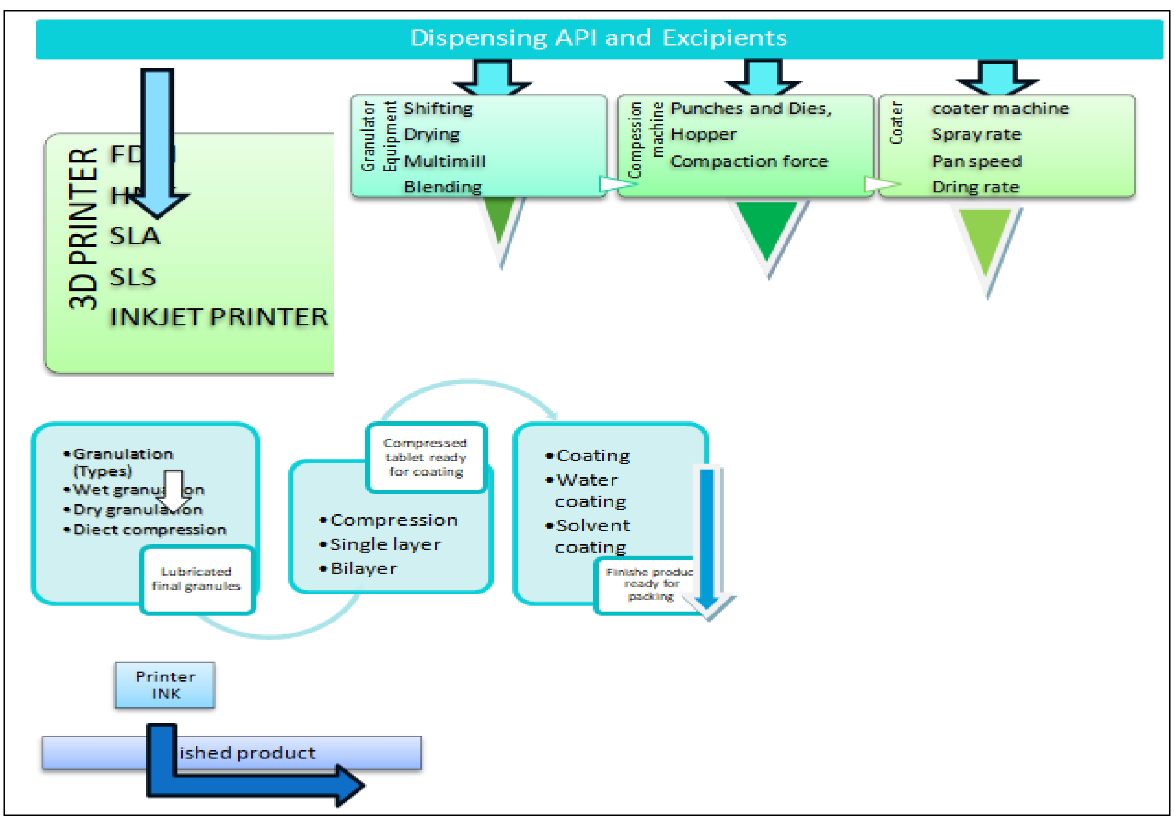


FIG. 3: KEY DIFFERENCES BETWEEN CONVENTIONAL AND 3D PRINTING METHODS

General Procedure for 3D Printing:

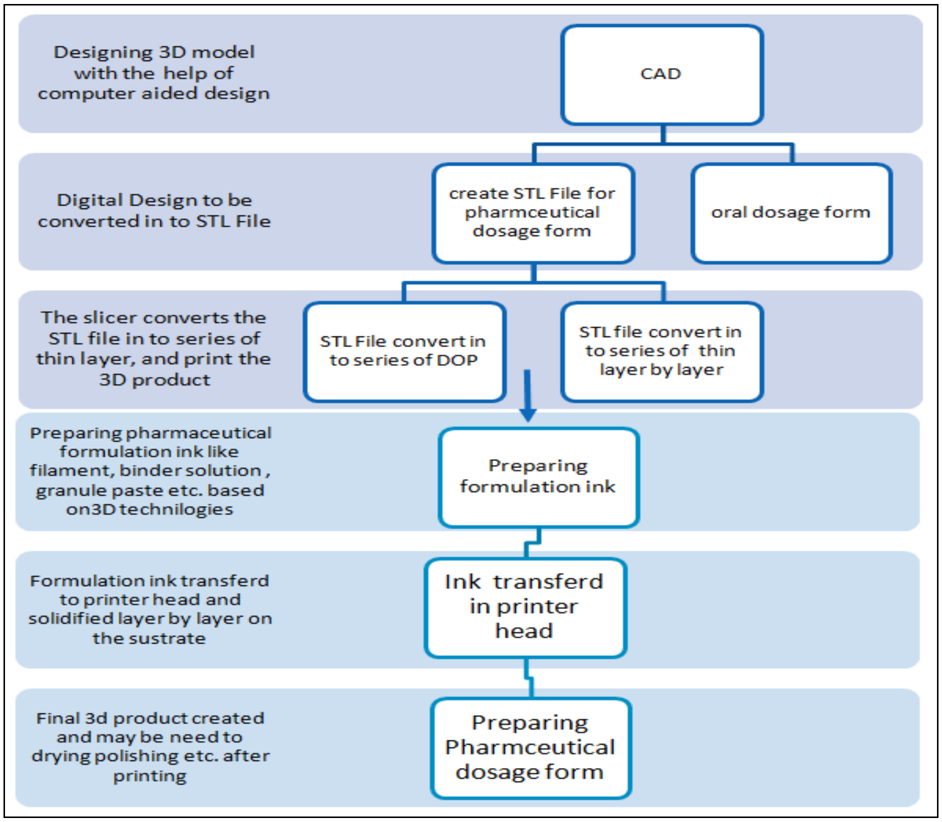


FIG. 4: THREE-DIMENSIONAL PRINTING PROCEDURE

Types of 3D Printing Techniques:

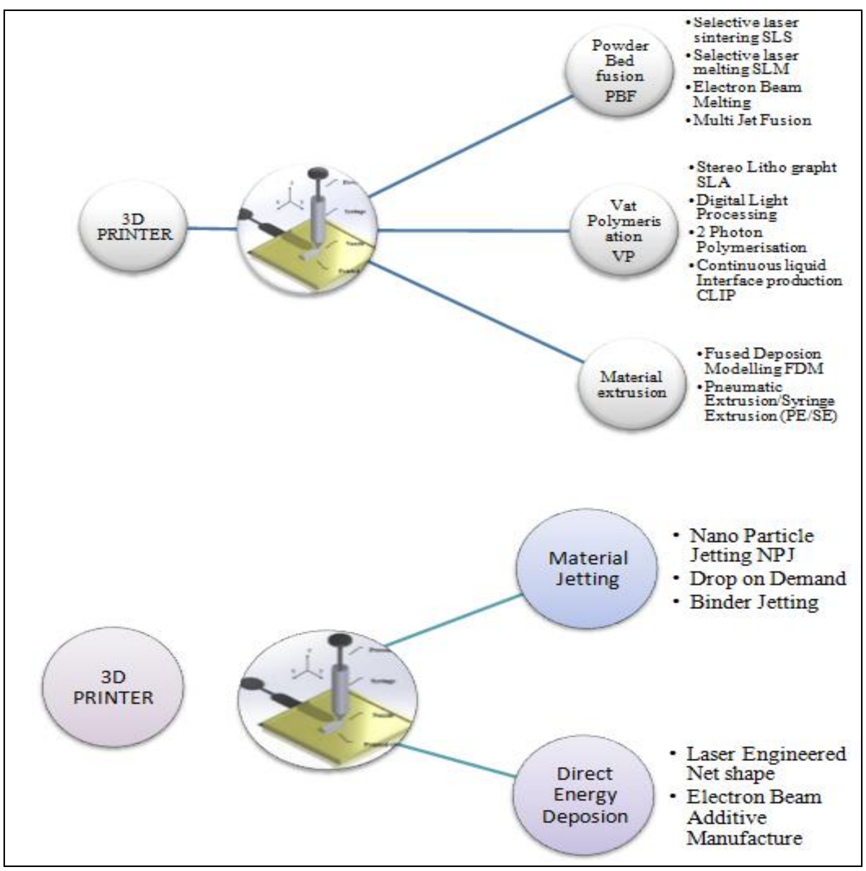


FIG. 5: TYPES OF 3D PRINTING TECHNIQUES

Fdm-Fused Deposition Modeling: Combined Deposition Applications such as developing, prototyping, and manufacturing frequently employ modeling. By stacking the components, it operates on the "additive" concept. The 3D printer has a spool of filament that is loaded and fed straight into the extrusion headset, where it is supplied to the printer nozzle. Melting the material with the aid of a heated nozzle may be manipulated both vertically and horizontally by a mathematically controlled mechanism and controlled by a computerized manufacturing (CAM) software program. A limited volume of thermoplastic material is extruded from the nozzle to create the model and construct the layers. The material is then solidified. Stepper motors are used to change the extrusion head. Quick modeling makes it easier to do iterative testing [21].

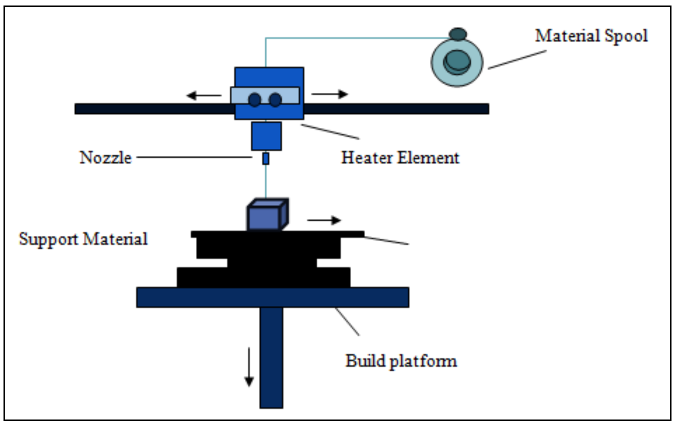


FIG. 6: FUSED DEPOSITION MODELING

Advantages:

- In many cases, the resolution of affordable 3D printers is good enough.
- More expensive versions employ a different material, and other materials are used for them. Plastic material is used hence it is cheaper in cost.
- There are many options and lower costs for printing.
- The medication is highly homogenous and friable.

Disadvantages:

- Sanding and eliminating leave marks are necessary for support.
- restricted research funding is anticipated for warping thermoplastic materials.
- The process starting material may degrade due to the high temperature.
- Advanced filaments are needed for the preliminary preparation.

Stereolithography (SLA): SLA was supposedly the first 3D printing technology ever developed. To commercialize his invention, Chuck Hull created a 3D printer, filed a patent, and invented stereolithography in 1986.

Galvanometers, one on the X-- and one on the Y-axis, are used in SLA systems. Using a resin vat to selectively cure and solidify the cross-section inside this building region, these aim at a laser beam and manufacture it layer by layer [22].

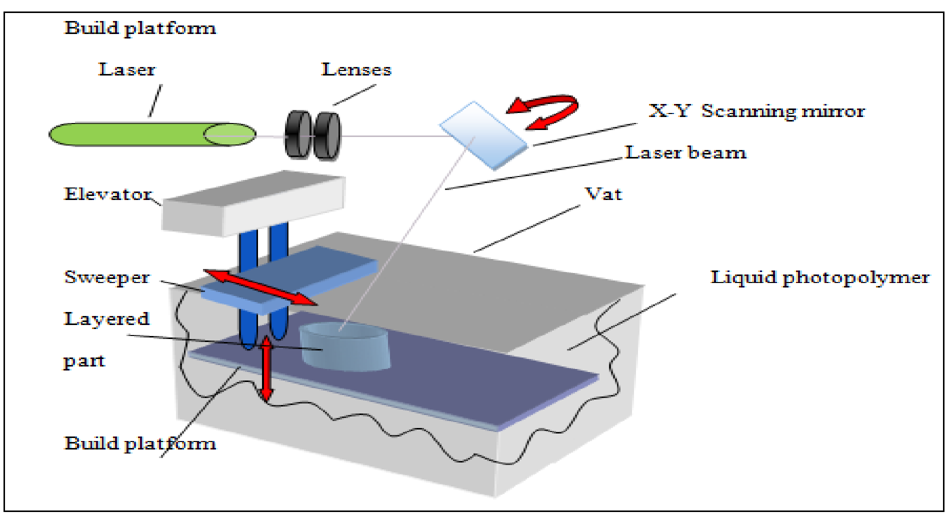


FIG. 7: STEREOLITHOGRAPHY

In stereolithographic 3D printing, polymerization processes are triggered by subjecting liquid resins or polymers to ultraviolet (UV) radiation or any other kind of high-energy light. As a result, photopolymerization is another name for it. Thus, the fundamental constraint on this approach is the requirement for photopolymerizable/photosensitive materials. The photopolymer undergoes a chemical reaction in the digital mirroring device used in stereolithography, which causes the exposed region to gel. The non-reactive functional groups that are bonded to the solid material in the first layer's polymerization, along with the lighted resin in the layer next to it, guarantee attachment before layers are formed. To prevent the item from collapsing during the printing process, certain backing structures are employed to join its various components. Post-printing processing is used to further improve the final product's mechanical integrity and polish or remove any connected supports to the printed topic [23].

Advantages:

- The object's dimensions are submicron and Deci micron.
- It is compatible with all other 3D printing technologies and boasts exceptional accuracy and resolution.

Disadvantages:

- Post-print curing
- Equipment is expensive.
- Take a long time

Selective Laser Sintering (SLS): This type of additive manufacturing uses lasers to fuse powder materials, much like SLA does, but with powder instead of resin. The powder bed is spread out in thin layers, and the layers are liquefied and fused using laser light. The powder is bonded layer by layer by a laser beam that sinters it [24].

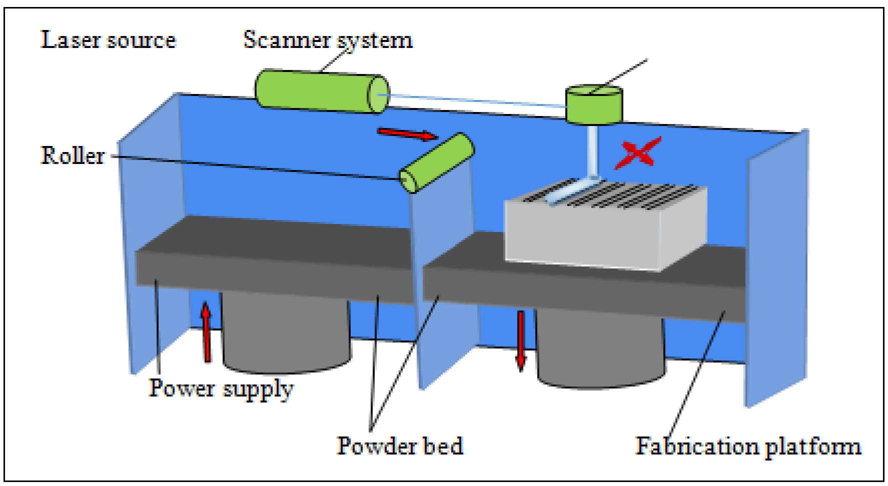


FIG. 8: SELECTIVE LASER SINTERING (SLS)

Advantages:

- High interior microstructure and porosity.
- Manageable and readily replicable.

Disadvantages:

- A post-printing finishing technique is needed.
- There is a limit on the sintering speed.

More energy inputs result in the beginning materials degrading.

Inkjet Printing: Using this method, a single jet is utilized to melt plastic habit material, which is then put in a container with the appropriate supporting material. Tiny particles of the liquid substance are fed into the flowing heads and raised in an X-Y pattern, which is required to build an object layer.

The substance hardens when the temperature is quickly lowered. The Thermo-Jet Modeller (TM), another name for the inkjet machine, is made up of a large head structure with a correct hundred nozzles. When everything is finished, a construction material matrix that resembles hair may be simply leveled to provide support for expansion. Solid-scape access is far slower than the inkjet machine [25].

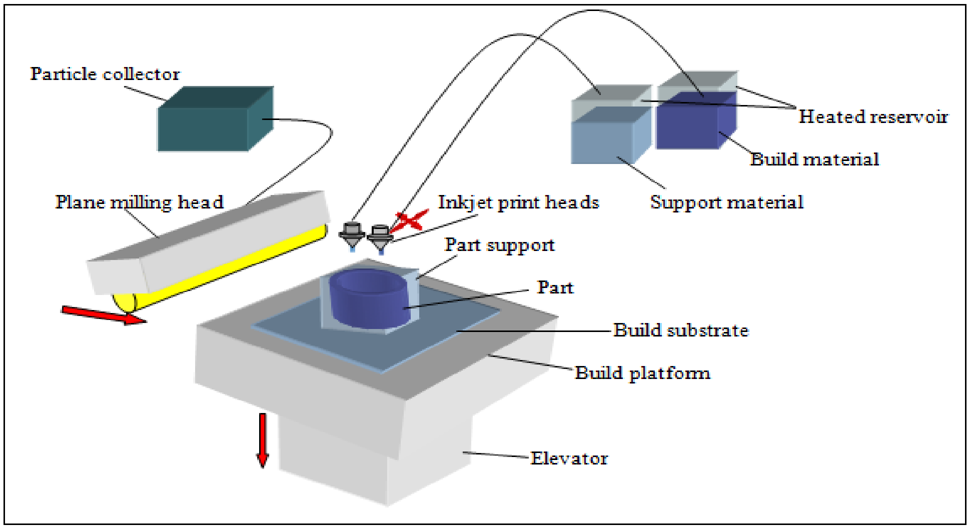


FIG. 9: INKJET PRINTING

Advantages:

- Faster production cycle with fewer processing steps.
- On-demand individualized dosing.
- Precise dosing
- Generation of minimal waste.

Disadvantages:

1. Only ink with precisely measured viscosity can produce proper ink flow.
2. The substance used to formulate ink should be able to bind itself, but not to other printer components. The ink may not have the necessary hardness in some formulations if it binds with other printer components or does not have sufficient self-binding properties.
3. The ink's binding to other printer materials may have an impact on the medication release rate.

Embedded 3D Printing: With embedded 3D printing, a new type of additive manufacturing is possible. A deposition nozzle is used to discharge viscoelastic ink along a predefined route into a solid reservoir. One of the earliest instances of using Embedded-3DP in the pharmaceutical industry to create chewable oral dosage forms with dual drug loading was demonstrated by Rycerz *et al.* The two medications that were utilized were ibuprofen and paracetamol, and they were suspended in a locust gum solution and a gelatin-based matrix embedding media. These were solidified at room temperature after being printed at a temperature of 70 °C. By specifically changing the printing patterns, different dosages were administered using printed dosage forms. The embedding phase's rheology, printing speed, and needle size were investigated. This proof of concept research demonstrated the possibility of using embedded-3DP to print oral dose forms with varying materials, enabling customized dosing and geometry for innovative oral dosage forms in pediatrics. [26].

Advantages:

- Made chewable oral dose forms with it.
- By specifically changing the printing pattern, the dosage form's dose was adjusted.

Disadvantages: A review was conducted on the embedding phase's rheology, printing speed, and needle size.

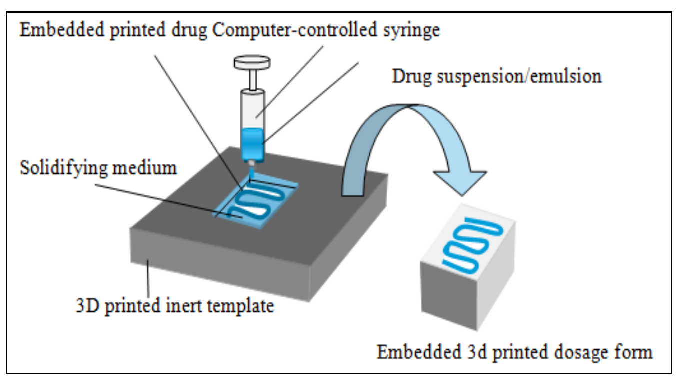


FIG. 10: EMBEDDED 3D PRINTING

Laminated Object Manufacturing (LOM): Developed by Helisys Inc. (formerly Cubic Technologies), it is a 3D printing technique.

Subsequently, adhesive-coated layers of paper, plastic, or metal are laminated together and laser-cut into the desired shape. After printing, objects created using this method can be further altered by machining. The material feedstock determines the normal layer quality for this process, which typically varies in size from one to several copies of a sheet of paper [27].

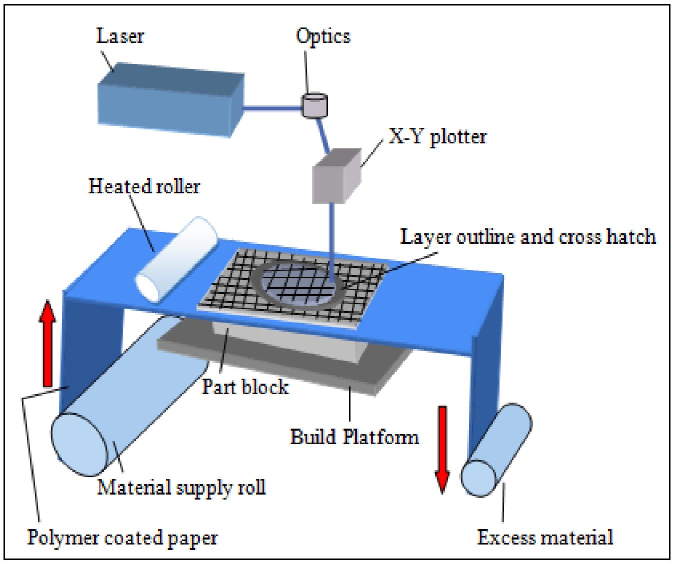


FIG. 11: LAMINATED OBJECT MANUFACTURING (LOM)

Advantages: Quick and inexpensive.

Disadvantages: Poor finishing.

Polymers used in 3D printing for Solid Dosage form: In the three-dimensional printing process, researchers used different polymers as well as merges to make new oral dosages forms polyvinyl alcohol (PVP) and polyvinylpyrrolidone (PVP) which polymers are most commonly used

Mainly Polymers used in 3D printing technology are classified into two categories

Non-biodegradable: PVP, polyethylene glycol (PEG), Edragit L 100, *etc.*

Biodegradable Polymer: Poly-L-lactic acid (PLLA), polycaprolactone (PCL).

Amalgams Blend two or more polymers, such as PLA with Eudragit RL PO

A list of Nonbio-degradable, Biodegradable, and amalgams (Combination of biodegradable and non-biodegradable polymers) used in 3DP Technologies are listed below in

TABLE 2: A LIST OF NON-BIO-DEGRADABLE, BIODEGRADABLE, AND AMALGAMS (COMBINATION OF BIODEGRADABLE AND NON-BIODEGRADABLE POLYMERS) USED IN 3DPTECHNOLOGIES ARE LISTED BELOW IN

Types of polymers	Name of polymer	3D printing technology	Employed hot melt extruder	Dosage form	Reference
Non-biodegradable polymer	Polyvinyl alcohol (PVP)	FDM/FFF	Single screw extruder (SSE) Conical screw extruder (CE)	Tablets	28293031
Non-biodegradable	Polyvinyl pyrrolidone - vinyl acetate copolymer (Kollidon VA-64	FDM/FFF	SSE	Tablets	32
			Co- rotating twin screw extruder (TSE)	Tablets	3334
			Conical screw extruder (CE)	N/A	35
			Ram extruder (RAM	Tablets	36
Non-biodegradable	Polyvinyl alcohol-polyethylene glycol graft copolymer (Kollicoat IR)	FDM/FFF	SSE	Capsule	37
			RAM	Tablets	36
			CE	Disc and capsule shell	3839
			TSE	Tablets	34
Non-biodegradable	Polyethylene glycol (PEG)	FDM/FFF	RAM	Tablets	36
			TSE	Tablets	36
Biodegradable	Polyvinyl caprolactam polyvinyl acetate-polyethylene glycol graft copolymer	FDM/FFF	TSE	Disc	40
			CE	Tablets	353841
Non-biodegradable	Polyethylene glycol diacrylate(PEGDA)	SLA	N/A	Tablets	42
Biodegradable	Eudragit RL	FDM/FFF	SE	Capsule shell, tablets	41
			SSE	Tablets	43

Biodegradable	Edragit EPO	FDM/FFF	CE	Tablets capsules,shell, Discs	[44]19,[4145]
Amalgams	Eudragit RL PO	FDM/FFF	CE	Solid disc	[38]
			SSE	Oral solid dosage form	[46]
			TSE	Tablets	[47]
Non-biodegradable	Eudragit L 100	FDM/FFF	TSE	Tablets	[40]
Non-biodegradable	Eudragit L 100 -55	FDM/FFF	CE	Discs	[38]
			RAM	Tablets	[36]
Biodegradable	Eudragit RS	FDM/FFF	CE	Tablets	[48]
Amalgams	Eudragit RS PO	FDM/FFF	RAM	Implants	[49]
Non-biodegradable	Eudragit E	FDM/FFF	CE	Tablets	[48]

Researchers produce many types of pharmaceutical dosage forms by 3DP technologies, but to date, only one formulation levetiracetam (spritam) available in the market and this drug was FDA-approved in 2015.Spritam is formulated as fast disintegrating tablet and is available in 4 different strengths 250mg, 500mg.750 mg and 1000 mg.

To date, many drugs have been investigated and converted into novel solid dosage forms by using different 3DP technologies

Some details like 3DP Technologies, polymeric ink, and instruments used for physiochemical studies are listed below in:

TABLE 3: SOME DETAILS LIKE 3DP TECHNOLOGIES, POLYMERIC INK, AND INSTRUMENTS USED FOR PHYSIOCHEMICAL STUDIES ARE LISTED BELOW:

3DP technologies	API	Dosage form	Polymeric ink	Physiochemical properties study by	Analyze	Ref.
FDM	Diltiazem	Caplet	PVP, Cellulose acetate (CA)	TGA, DSC, X-ray diffraction (XRD) and electron microscope	Physiochemical properties and Morphological features	[50].
FDM-HOT melt extruder	Pramipexole dihydrochloride monohydrate	Tablets and filaments	Eugtagit EPO+POLYOXTM WSR N 10 and Eudragit EPO +POLYOXTM N80	Scanning electron microscope (SEM) differential scanning calorimetry (DSC) and filament disintegration test	Assess the characteristics of prepared filament and tablets	[51]
SLS	Ondansetron and antiemetic drug	Oro dispersible printlet	Kollidon VA-64	DSC, SEM, Micro-CT, XRD HPLC	N/A	[52]
PAM	Captopril,nifedipine and glipizide	Tablets	HPMC (USED AS PRIMARY POLYMER for glipizide and nifedipine)and PEG600 and cellulose acetate (CA) for captopril drug released via osmotic diffusion))	SEM, DSC, XRPD	Release profile of polypill and study morphological features	[5354]
FDM -Hot melt extrusion	Isoniazid and rifampicin	Printed in two-layer and fused to make a single layer of Tablet	HPMC FOR Isoniazid and Hydroxymethyl propyl cellulose-succinate (HMPCAS) for rifampicin	SEM, DSC, XRPD, HPLC	Study Physiochemical properties	[55]
FDM	Metformin HCl	Metformin - PVA (ML-PVA) filaments	PVA Filament and to enhance the solubility of the drug, ethanol is utilized as a solvent of metformin then PVA filament is socked in	SEM,X-ray diffraction (XRPD), furrier transform infrared spectroscopy (FTIR), DSC, and	Study physiochemically characterize	[56]

			metformin HCl /ethanol solution for a specified time, then the solution is aliquoted in several vials and continuously stirred for 1, 3, and 10 days to achieve maximum drug loading	dissolution studied		
FDM	Ciprofloxacin HCl	Flat-faced cylindrical printlets (Drug loaded filaments of diameter 2.85+-0.15mm are used to feed the extruder	Ciprofloxacin HCl +PVA'S drug-loaded filament (Dried powder of drug and polymer mixed and prepared physical blend, Dibutyl subacute added to increase drug adhesion to pellets	SEM DSC	Study release profile and physiochemical characteristic	57
Water-based inkjet	Tablets	Thiamine Vitamin B1)	Polyvinyl pyrrolidone	SEM, DSC, XRPD	Study physiochemical properties	58
FDM	Tablets	Prednisolone	PVA	DSC, XRPD, SEM	N/A	59
FDM	Oro-dispersible film	Aripiprazole	PVA	XRD, DSC, SEM	N/A	60
FDM	Tablets	Ibuprofen	Ethyl cellulose	SEM, DSC, XRPD	N/A	61
Extrusion based	Bilayer tablets	Guaifenesin	HPMC +Polyacrylic acid	DSC, SME, XRPD	N/A	62
Extrusion based	Tablets	Paracetamol	Polyvinyl pyrrolidone	SEM, DSC, XRPD	N/A	63
Inkjet based DOP	Tablets	5--fluorouracil	2-pyrrolidone	SEM, DSC, XRPD	N/A	64
FDM	Tablets	4- amino salicylic acid	PVA	SEM, DSC, XRPD	N/A	65
FFF	Tablet	Theophylline	HME+Poly- meta acrylate-based copolymer	SEM, DSC, XRPD	N/A	66
Extrusion-based 3D printer	Gummies(Solid dosage form	Ranitidine HCl	Carrageenan+Xanthan gum	DSC, XRD	N/A	67
FDM	Tablets	Theophylline	HPMC+K4M	SEM, Textural Profile Analysis (TPA)	N/A	68
FDM -Hot melt extrusion	Tablets	Anhydrous caffeine	Hydroxy propyl cellulose +Vinyl pyrrolidone-vinyl acetate (copolymer)	DSC, Confocal, Raman microscopy	N/A	69

Application of 3 Printing Healthcare and Pharmaceutical Sector:

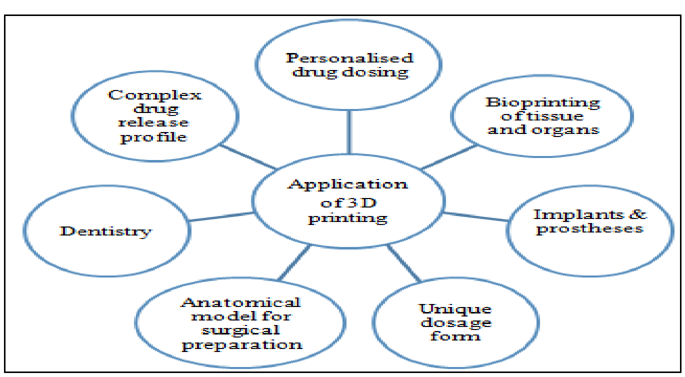


FIG. 12: APPLICATION OF 3D PRINTING

Personalized Drug Dosing: Research in pharmaceuticals is beginning to focus on customized medication administration. It has been noted that even when individuals have the same conditions, their problems may differ and necessitate distinct treatment plans. For example, patients undergoing combination drug therapy may need to take various medications at different times of the day. Furthermore, a one-size-fits-all strategy is dubious since the bioavailability of various patient populations (such as newborns, children, adults, and the elderly) might differ significantly. Moreover, because pharmaceutical companies are unwilling to produce goods with a small target market and must pay for waste, storage, transportation, and other expenses associated with overproduction, patients with rare diseases occasionally cannot find a medication with an appropriate dosage [70]. When it comes to the advancement of personalized medicine, 3D printing technology is a crucial instrument. Customizing medicine dose forms, release profiles, and dispensing for every patient is made possible by 3D printing technology. The medications themselves can be customized to suit a wide range of exact requirements and the particular requirements of people using them [17]. Individualized 3D-printed medications might be especially helpful for individuals using medications with limited therapeutic indices or those with pharmacogenetic polymorphisms. Pharmacists might estimate the ideal medicine dose by examining a patient's pharmacogenetic profile together with other factors like age, ethnicity, or gender. The customized drug might then be printed and dispensed by a chemist using 3D printing technology. Depending on the clinical response, the dosage may need to be modified further [71].

Some Examples of personalized dosage form sprinted by 3DP are given below:

TABLE 4: SOME EXAMPLES OF PERSONALIZED DOSAGE FORMS PRINTED BY 3DP ARE GIVEN BELOW:

Application	Release profile of Drug	Types of Formulation	3DP technology	Polymers	Ref.
Personalized dosing	Hydrogel	Ibuprofen	SLA	PEGDA,PEG 300	72
	Immediate release (Drug release with fiction diffusion)	Ropinirole hydrochloride tablet	Inkjet with photo initiation	PEGDA (Cross-linked polyethylene glycolate hydrogel matrix	73
	Channel tablets (Enhanced release rate of the eluting drug from the polymer-rich structure	Hydrochlorothiazide	FDM	Croscarmellose sodium, Sodium starch glycolate, Crosslinked PVP	74
	Candy-like formulation (Pediatric medicines with enhanced palatability	Indomethacin	HME coupled with FDM	Hypromellose acetate succinate (HPMCAS) and polyethylene glycol (PEG)	75

Unique Dosage Forms: Employing "inkjet-based 3D printing drug fabrication," which involves employing inkjet printers to precisely spray drug formulations and binders in minute droplets onto a substrate at specific speeds and movements, these dosage forms are produced.

A range of a substance called coated or uncoated paper, optical scaffolds, metal alloys, microporous bioceramics, and potato starch films are among the most often utilized substrates.

By spraying homogeneous "ink" droplets onto a liquid layer that encases it, the researchers enhanced this technique even further by creating microparticles and nanoparticles. These matrices can be employed to distribute growth factors and tiny hydrophobic compounds.

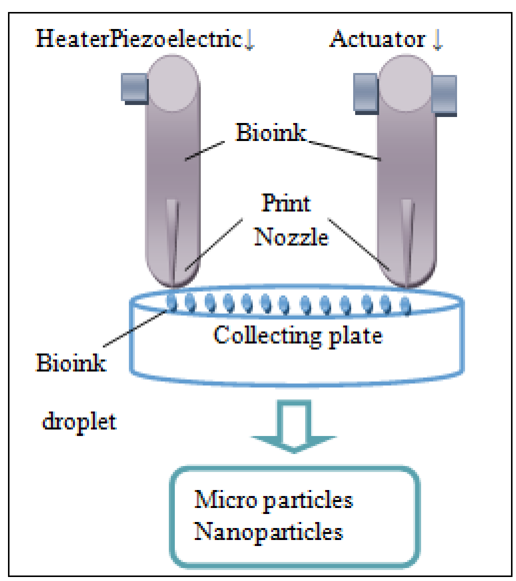


FIG. 13: THE INKJET 3D PRINTING TO PRODUCE MICROPARTICLES AND NANOPARTICLES

The "ink" is sprayed onto the powder foundation by the inkjet printer head in "powder-based 3D printing drug fabrication." Layer by layer, the ink solidifies and becomes a solid form of administration when it comes into touch with the powder. In addition to binders and other inert chemicals, the ink also includes active compounds. Upon drying, the solid item is extracted from the adjacent loose powder substrate of the 3D-printed dosage form. Additionally, this technique allows for the creation of an infinite number of dosage forms, which is expected to pose a threat to traditional medication production. Numerous innovative dosage forms, including mesoporous bioactive glass scaffolds, multilayered drug delivery devices, antibiotic-printed micro patterns, hyaluronan-based synthetic extracellular matrix, microcapsules, and nanosuspensions, have previously been produced using 3D printers [71]. A summary of some unique dosage formsis given below in **Table 5.**

TABLE 5: A SUMMARY OF SOME UNIQUE DOSAGE FORMSIS GIVEN BELOW:

Application	3DP technologies	Dosage form	Formulation	Polymers	Ref.
Unique dosage form	FDM	Drug-eluting device	Specifically designed subcutaneous rod and T-shaped intrauterine indomethacin delivery system	EVA,PCL	7677
	Extrusion	Biodegradable patch (Sustained delivery up to 4 weeks)	A 5-fluorouracil patch was applied precisely at the location of the tumor with a measurable form	PLGA,PCL	78
	Inkjet printer	Scaffold	Caspase scaffolds loaded with rifampin and vancomycin	Polymethyl methacrylate (PMMA)	79
	Microneedles	Polymeric microneedle patches	Insulin delivered via the skin	Dental SG, Resin xylitol, mannitol, Trehalose	80
	Hot-melt Extrusion based	Biofilm disk Geometrics model(Modified release)	Nitinofurantoin disc geometries model	PLA, HPMC	81
	3D printed macro/meso porous composite	Implant	For osseous regeneration, isoniazid and rifampin are used in conjunction with local multidrug treatment.	3 Hydroxybutyrate-co-3 hydroxy-hexanoate (PHBHHx)	82
	Inkjet printer	Slow-release implant	implanting an isoniazid Paclitaxil microparticle with a precisely shaped and regulated form	PLLA	83
	Inkjet +Powder bed with Piezoelectric Dimatrix printer	Particularly in shape-controlled release	implanting an isoniazid Paclitaxil microparticle with a precisely shaped and regulated form	PLGA	84
	Inkjet printer	Implant complex drug release	Levofloxacin-containing implants for intricate drug release profiles	L-PLA	85
	SLS	Fast Release	(Drug administration device with unique internal structure characteristics) Paracetamol	HPMC, Vinylpyrrolidone-vinyl acetate copolymer	86
	SLA	Hydrogel form	Ibufrofen -loaded hydrogel	PEGDA, PEG300,dipheny l(2,4,6-trimethyl benzoyl) phosphine oxide or riboflavin and triethanolamine	72
	FDM	Dispersion form(Controlled release)	Solid dispersion of felodipine	PEG,PEO, Tween 80 with either Eudragit EPO or Soluplus	87
	Inkjet printer	Film form	Rasagiline mesylate orodispersible	Cross-povidone	88

		film	(Kollidon CL-M)	
Cellulosic Tablets(Rapid drug release due to swelling of cellulosic polymer)	FDM	Theophylline	HPC, sodium starch glycolate, croscarmellose sodium	89
Scaffolds Tablets(Release drug through diffusion erosion mechanism	FDM	Ibuprofen	Ethylcellulose	90
Oral dissolving film(Quick disintegrate,immediate release)	FDM	Aripiprazole	PVA	91
Zero-order drug release Gastro-retentive floating tablets(Control release)	FDM	Metronidazole	PVA	92

Complex Drug Release Profile and Multi-Drug Combination: A straightforward drug release profile, or a uniform combination of active ingredients, is seen in the majority of traditional compressed dosage forms. In contrast, a complicated drug release profile in 3D printed dosage forms has been seen, which enables the development of complicated geometries that are porous, packed with numerous medications throughout, and encircled by barrier layers that regulate the release. The 3-D printing of a monolayer bone implant with a distinct medication release profile that alternates between isoniazid and rifampicin via a pulse release mechanism serves as one example. To completely remove the Staphylococcus epidermis, antibiotic micropatterns have also been printed using 3D printing on paper and utilized as medication implants. Chlorpheniramine maleate, in quantities as tiny as 10-12 moles, was 3D created on the fiber powder substrate in a drug release profile study to show that even a small amount of the drug may be released at a predetermined period. This study shows that routinely made medications are less accurate when it comes to the release of extremely tiny pharmacological dosages [93].

Unlike immediate-release medicines, sophisticated or modified-release dosage forms are designed to administer the active ingredient gradually and continuously across the whole dosing interval to maximize a treatment regimen. Such dose types are frequently referred to by synonyms like "controlled release," "extended release," or "delayed release." This results in higher therapeutic adherence and fewer dose intervals (Karalia *et al.*, 2021). Many options are available for modifying tablet geometries and medication release through the use of different polymers and filling fractions in additive manufacturing.

Goyanes and colleagues, for instance, used PVA filaments and the FDM process to create modified medication release tablets containing 4 and 5 ASA. FDM worked well for 5-ASA; however, 50% of the potent 4-ASA was thermally degraded during printing, indicating that this process might not be appropriate for medications that are sensitive to heat. Furthermore, three distinct loading rates (10%, 50%, and 90%) were written on the tablets, and it was found that the tablets with higher filling percentages had better thickness and mechanical strength along with delayed drug release

Because they must take many medications at different doses in a single day, elderly people have a high likelihood of noncompliance with treatment regimens. Creating a "Polypill," or one-pill formulation with many drugs, each with a unique release profile would enhance adherence to the regimen and ultimately improve the quality of life for the senior population. Depending on the patient's needs, these tablets may be made with a once-daily dosage or even a longer prolonged release. FDM and SSE were used in tandem to deliver many drugs in a single dosage form in one particular experiment. Polypill included a comprehensive cardiovascular therapy regimen in addition to extra compartments holding sustained-release forms of atenolol, ramipril, and pravastatin. The quick digestion of ibuprofen and hydrochlorothiazide was facilitated by a chamber in this regimen.

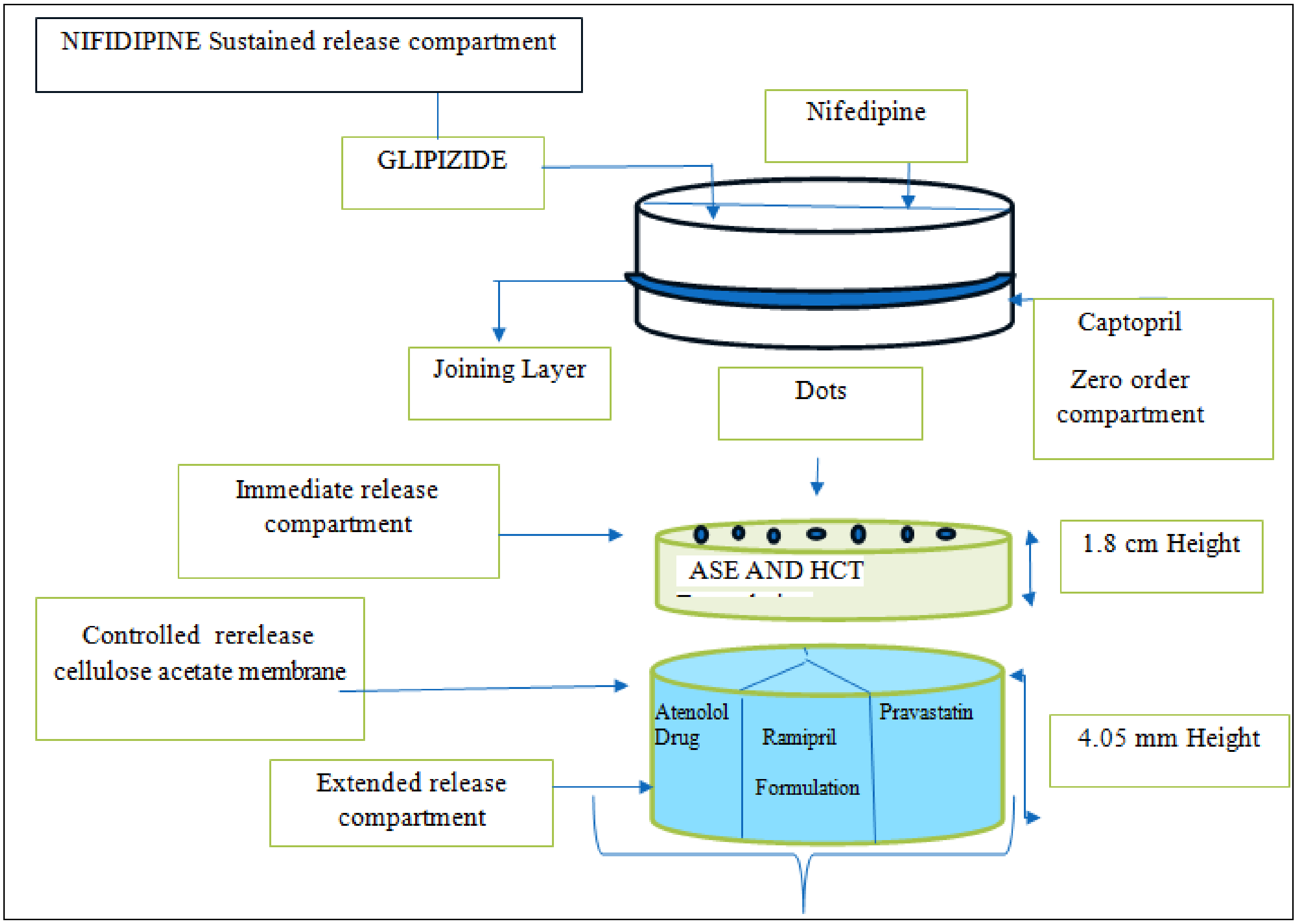


FIG. 14: PARTITIONED STRUCTURAL SCHEMATICS OF THE POLYPILL DESIGN, DISPLAYING COMPARTMENTS FOR PRAVASTATIN, RAMIPRIL, AND ATENOLOL WITH IMMEDIATE RELEASE AND SUSTAINED RELEASE, RESPECTIVELY

TABLE 6: A SUMMARY OF COMPLEX DRUG DESIGN AND POLYPILLS IS GIVEN BELOW:

Application	Drug release profile	Dosage form	Formulation	Polymers	Ref.
Complex drug release profile	Extrusion based	Polypill	Five compartmentalised drug (aspirin,hydrochlorotiazide, ramipril, pravastatinand atenolol	HPMC	94
	Extrusion based	Polypill drug release via osmotic pump	Tablet with prolonged-release compartments for glipizide and nifedipine (a multi-active polypill tablet plus an osmotic pump with captopril)	HPMC	94
	FDM+Hot melt extrusion	Implant (polypill)	dual compartment unit rifampicin and isoniazid (Programmed prolong release)	PLA	95
	Ho melt inject	Tablets	Fenofibrate (Various release profiles obtained by changing the geometry)	Bees-wax	96
	FDM	PLA Pellets	Gentamycin (Retained the bioactivity)	PLA	97
	FDM	Immediate release	Dipyridamole or theophylline(Tablets	PVP	98

		with several model drugs)		
FDM	High drug release	Tablets of halioperidol	Kollidon VA64+Affini-sol 15 Cp1:1,Kollidon VA64 +HPMCAS 1:1	99
SSE	Fickian diffusion drug release through a hydrated HPMC gel layer	Bilayer tablets of guaifenesin	Polyacrylic acid (PAA),Sodium starch	94
FDM	Modified release	Tablets of 4- aminosalicylic acid and paracetamol	PVAfilaments	100
FDM	Extended-release	Tablet of prednisolone	Polyvinyl alcohol (PVA)	101
Inkjet printing	Drug release with fiction diffusion	Ropinirole HCL	Cross-linked polyethylene glycol diacrylate (PEGDA)hydrogel matrix	96
FDM3DP	Controlled release	Felodipine Tablet(Solid dispersion)	PEG,PEO,Tween 80 with either Eudragit E PO or Soluplus	87
Hot melt extrusion	PLA-HNT nano-tubes	Gentamycin(anti-microbial growth inhibition effect)	PLA	102
FDM	Scaffold tablets(release drug through diffusion erosion mechanism	Ibuprofen	Ethylcellulose	90

Dentistry: Dental professionals are increasingly using 3D printing technologies. Among its many applications are the creation of orthodontic surgical models and replacement teeth. Invisalign is one product that exemplifies this since it straightens teeth without the need for traditional metal braces by using transparent orthodontic devices that are created in 3D We now employ a piece of small scanning equipment, and patients submit molds to specialist facilities for screening, and the manufacturing of retainers. Although this process is time-consuming, patients' deformed teeth might eventually be scanned with a tiny intraoral device. Digital dentistry services, like the recently released semisolid extrusion printers Crown Worx and Frame Worx, might be made by transmitting the computerized scanning to a nearby 3D printer so that retainers can be made. The printer extrudes a kind of wax used in dentistry facilities to create personalized crowns and bridges. Polymeric resin (polymethyl, methacrylate) and titanium dioxide can be used to make patent-specific dentures with unique antimycobacterial properties using 3D printing technology.

Recent advancement to produce patient-specific composite tissue for tooth tissue engineering example of Dentistry by 3D printed technology.

TABLE 7: ADVANTAGES OF PHARMACEUTICAL3D PRINTING

Application	3DP technology	Polymer	Ref.
Dental model	DLP	Photosensitive resin	103

Advantages of Pharmaceutical 3D Printing:

1. This is feasible to develop tablets in any size or shape using 3D printing.
2. It can customize the dose for every patient.
3. Minimize the quantity of dose by substituting a great number of pills with one.
4. Customized and personalization of the pioneering benefits of this technology is the liberty to manufacture customized medical devices and products. Customized implants, prosthetics, fixtures, and surgical tools can be a great advantage to patients as well as physicians.
5. Droplet size control, intricate drug release profiles, dose strength, and multi-dosing are all made possible by 3DP.
6. It is possible to obtain accurate and precise dosing of strong medications.
7. With 3D printing, it is simple to make pills that are easy to dissolve.
8. Treatment can be modified to increase patient adherence when using several drugs with multiple dosage regimens.
9. Cost-effectiveness is increased since 3D-printed items have a low coat. The fact that nearly all of the elements are

	affordable is advantageous for businesses that produce extremely complicated goods or parts or for small-scale production units.
10.	It controls the quantity of active ingredients in the tablet's composition by removing or substituting certain parts. This will enable many people to use the medications even in cases when there are specific ingredient contraindications.
11.	Using 3D printing, dosage forms that control the overall circulation of API may be created.
12.	With a prescription from a doctor, patients may now receive more pharmaceuticals from any drugstore that has a 3D printer thanks to this technology.
13.	Compared to traditional dosage forms, drugs created using 3D printing offer a larger drug loading capacity.
14.	By the use of this technology, one can accurately assess the demand for pharmacies.
15.	Compared to the conventional approach, it might produce small quantities of medications and minimize the costs of drug manufacture and testing.
16.	Increased productivity: 3D printing is more efficient than traditional techniques, especially when producing items like implants and prostheses. It also offers greater repeatability, precision, and dependability in addition to superior resolution.

Disadvantages of Pharmaceutical 3D Printing: Even though adopting 3D technology to produce pharmaceutical items has several benefits, it has some disadvantages also which are described below:

1.	Since the structure of finished items is impacted by the print head shutting, nozzle issues provide a significant obstacle.
2.	Blocking of powder printing is a further issue.
3.	The impact of ink formulations, storage environment modification, and the potential to modify the final component to mechanical stress.
4.	Printer-specific factors and their impact on print quality and cost [104].
5.	The use of high-energy input in extrusion-based printing technology has prompted worries about the deterioration of thermo sensitive materials, which is a major downside and limits the technique to largely thermostable materials [105].
6.	If a created layer is not hardened enough to support the total weight of the subsequent layers, the generated 3D products might break down during 3D printing, resulting in poor hardness and extremely friable 3D goods[106].
7.	The biggest obstacles in the usage of 3-D printing is process optimization, equipment performance improvement for flexible use, appropriate excipient selection, and post-treatment method selection. These issues must be addressed to improve the performance of 3D printed products and increase their scope of use in new methods for drug delivery.
8.	Certain 3D printing technologies can create dosage forms with irregular shapes and very permeable materials. One controlling step in the application of the fused deposition modeling approach, for instance, is to limit the use of adjuvants to those that are readily accessible and thermostable pharmaceuticals only.
9.	The largest disadvantage of all 3D printing techniques, both in terms of technological limitations and when compared to conventional manufacturing techniques, is the output yield. While a conventional tableting technique may utilize a press to make more than 15,000 tablets per minute, the typical manufacturing time for a single tablet utilizing 3D printing can range from 2 minutes to 2 hours, depending on the process employed.
10.	One of the challenges in stereolithography is the potential for drug degradation as a result of materials being exposed to UV radiation, which can cause a polymerization reaction
11.	Additional common issues with the majority of 3D printing techniques include layer thickness fluctuation, a comparatively small selection of materials, and the possibility of unaffected initial material in the finished product.

Challenges of 3D Printing: Implementing personalized medication raises many challenges, chief among them being patient acceptability among other parties involved in the healthcare system. It might be difficult to teach and prepare medical personnel to use customized medicine. This is because, in personalized medicine, as opposed to traditional practice, physicians are also tasked with identifying the best course of action for each patient by first assessing their unique characteristics, including behavioral, genetic, and biochemical aspects. Because there may be worries that personal data would be used fraudulently, this might give rise to privacy and legal difficulties. Furthermore, the full and successful implementation of personalized medicine will need the identification of millions of genetic variants. Many genes, not just one, may interact to determine how an individual reacts to a medication. Consequently, it might be expensive and time-consuming to go through genetic profiles and maps and comprehend their impact before reaching a diagnosis or starting a treatment. To enhance healthcare, pharmacogenomics is still expected to be included in standard medical procedures. Furthermore, the validity and accuracy of genetic testing are still improving, but there are still issues with how test findings should be interpreted and communicated [107]. Another significant obstacle to the efficient use of personalized medication is getting regulatory organizations to approve the creation and usage of customized dosage forms. These issues center on the necessity of demonstrating the superiority of personalized medication tactics over traditional medicine techniques, which is especially important given the possibility of higher costs associated with customized medicines. As the practice grows, more effective tactics must be created to cater to the demands of certain patients. Implementing health insurance policies concerning the ethical and legal manufacture of personalized medication is another difficulty for healthcare professionals, management of hospitals, and healthcare plan sponsors in realizing personalized medications because customized pharmaceutical practice requires the reform of current healthcare structures and payment systems, especially those that relate to genetic testing and customized treatments [107].

Future Prospective: Numerous forms of 3DP are being used in more and more studies. Personalized medicine is one of the key benefits of all forms of 3DP that are now accessible. Because of attainability, speed, and simple usage, additive manufacturing is encouraging the production of pharmaceuticals and medical equipment on demand for patients in a clinical environment. Varieties have the potential for three-dimensional printing in the health care profession, as evidenced by the capacity to modify the dosage profile and dose of 3D-produced tablets by utilizing CAD to adjust their geometry and the possibility to insert pharmaceuticals into FDM-manufactured intravenous equipment or mesh implant using HME.

Before the creation of on-demand 3D-printed items can be realized in a clinical context, further study is necessary to understand the effects of process variables that affect the printing experience and their effects on improving repeatability in 3DP. Because the pharmaceuticals must resist the high temperatures involved in the process, the amount of drugs that may be put into filaments is another constraint on FDM. But if 3DP research keeps on, more 3DP will probably make it past the idea indication stage and become widely utilized manufacturing equipment the adaptability of three-dimensional printed goods as well as a multitude of production benefits they offer. The US FDA released guidelines for employing 3DP technology in the manufacture of healthcare devices to hasten the use of this technology. As a result, we anticipate seeing an up rise three three-dimensional printed pharmaceutical and medical items on the market in the next years.

Market Growth and Potential of 3D printing Technologies [108]: The three-dimensional printing market is expected to have grown between USD 20.24 billion in 2023 to USD 56.21 billion at a CAGR of 22.66% (2023 to 2028)**.** The technique known as 3D printing allows for the creation of items and opens up new possibilities for the manufacturing, design, and use of innovative building materials, systems, and architectural forms. It is a creative, quicker, and more flexible approach to product creation and manufacturing.

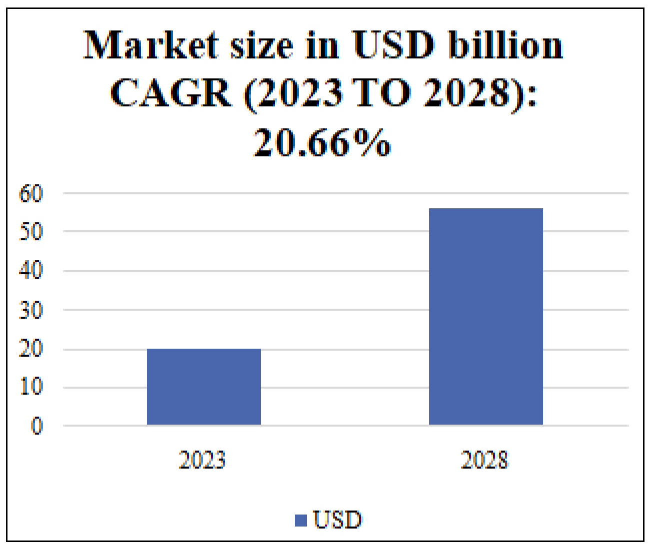


FIG. 15: MARKET GROWTH IN 3D PRINTING

The variety of categories for the three-dimensional print process: are desktop and industry-grade printers; ceramic, metal, and plastic materials; industries (automotive and defense, topography; and medical care, building, art, power, and foodstuff. Selective laser sintering, or SLS, has been used process in every industry for 3D printer innovation since it offers several advantages over other technologies. Selective laser sintering, or SLS, has been used process in every industry for 3D printer innovation since it offers several advantages over other technologies. The majority of industry and research institutions throughout the globe have been noted as utilizing this substance and technology to address issues including the resin's brittle nature when exposed to light.

SLS does not require a specific post-printing support structure; instead, it only has to be economical and material-friendly. Furthermore, SLS offers improved durability and may be used for prototypes or functioning products. Applications for SLS technology include aerospace, defense, and the automobile industry. A paradigm change is occurring in space exploration, and the necessity for printing as more countries are ready to build satellites with SLS is predicted to grow. Furthermore, SLS is being utilized more and more in electric and sports automobiles. Prominent automotive enterprises have been employing SLS 3D printing methods in their electric vehicles and anticipate a surge in demand worldwide, propelling technological advancements. The percentage of 3D printers that are used most frequently is graphically shown below:

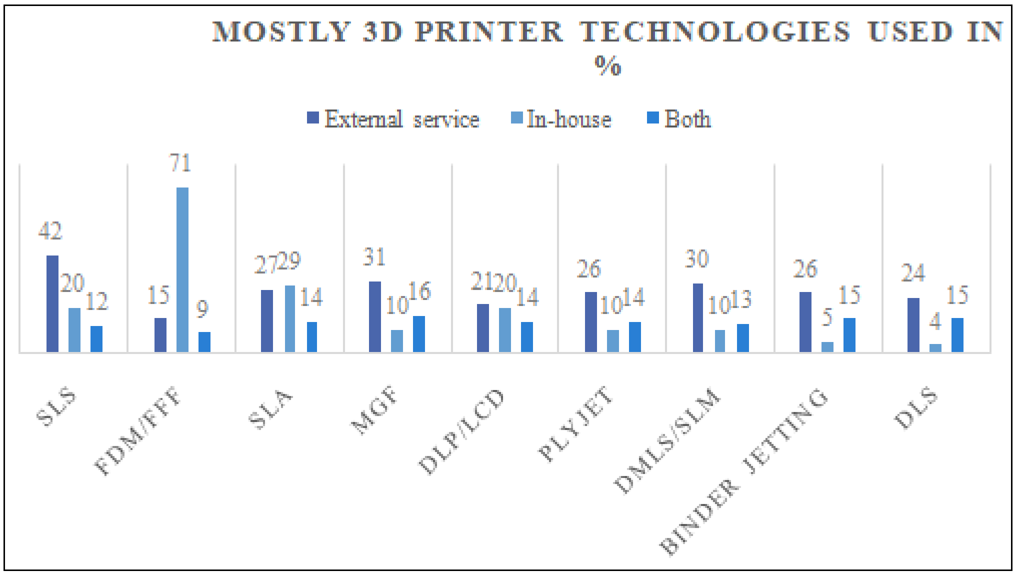


FIG. 16: THE PERCENTAGE OF 3D PRINTERS THAT ARE USED MOST FREQUENTLY IS GRAPHICALLY SHOWN BELOW:

Role of 3D Printing for Industrial Growth: ExOne and Maxwell Motor Announced their partnership to create 3D-manufactured copper windings in August 2021. Thanks to this partnership, Maxwell Motors can now include a newly created, distinctive copper winding design into a cutting-edge axial flux electric motor, which is ideal for usage in heavy-duty vehicles, electric automobiles, and industrial equipment.

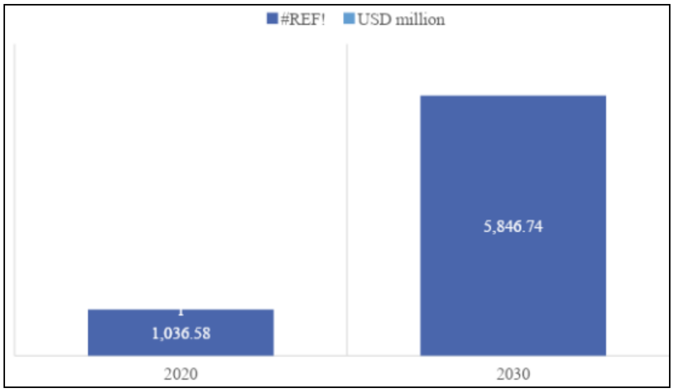
Customer tastes are predicted to change and 3D printing technology to be driven by activity monitors and smart attire.

Saremco Dental AG and 3D System joined forces in February 2022 to promote innovation in digital dentistry. Through this collaboration, dental laboratories and clinics will be able to handle an array of demonstrations of exceptional reliability, consistency, and creativity, and reduce overall price thanks to the combined strengths of three dimensions complex leads the way Digital dental treatment from NextDent and Sarco's material science expertise.

One of the world's foremost providers of 3-D printing solutions and sophisticated manufacturing technologies, Imaginarium, announced in February 2022 the introduction of its personal and corporate 3D printer line in collaboration with the industry titan Ultimaker. October 2022: The Australia metal three-dimensional prints company AML3D increased cooperation with the Boeing Company. An adjustable Acoustic displacement (VAD) process the mixture enhances EOS printing device marked of products and simplifies gross depowering for 3D printed parts. Post-process technologies and EOS announced a distribution relationship in October 2022. Post-process will available EOS completely autonomous and rational solution.[109]

In Healthcare: Healthcare 3D printing market - According to the product (Inkjet, laser-based, magnetic levitation, syringe) Through technology (Selective Laser Sintering, Stereolithography, Fused Deposition Modelling), By Application (Medical, Dental, Biosensor) and Forecast (2020–2030)

Healthcare 3D printing market approx. 1,036.58 million in 2020 and anticipated to cover over 22.5% CAGR from 2020 to 2030.



The need for prostheses that closely resemble patients' physical features is growing as a result of ongoing advancements in healthcare technology. In recent years, three-dimensional print equipment made extensive use in pharmaceutical as well as medical industries. Benefits include reduced manufacturing costs, patient recovery times, and time savings have the use of three-dimensional processes in the healthcare industry.

Increasing Demand for Syringe Pump Extruder Across 3D Bioprinting Applications: Global medical care for three-dimensional trade expenses in legacy:

In 2022, the syringe-based medical care 3-D printing market is expected to be worth about USD 980 million. Bioprinting and integrated printing are only two of the many uses for syringe-based 3D printing. Syringe-based 3D printers have become more popular as a result of growing demand for highly flexible and precise production systems. These printers assist shorten the time between design and prototype and facilitate the creation of tiny syringes more quickly.

Minimally invasive surgery trends boost medical application stereolithography:

From 2023 to 2032, the stereolithography technology-based health 3D printing market is anticipated to expand at a pace of compound annual growth of more than 22%. In recent years, stereolithography has become a viable technology for medical segmentation, layering, and 3D model prototyping. Diagnostic and preemptive planning in the healthcare industry are being revolutionized by this technology. The industry appearance will be enhanced by the widespread adoption of stereolithography for the very accurate manufacturing of massive components with excellent surface quality.

Rise in the Demand for Dental Implants to Spur the Industry Expansion: By 2032, the dental uses of 3D printing in healthcare are expected to generate over USD 5.5 billion in revenue. Healthcare 3D printing is widely used to make dental implants, including crowns, dentures, and bone grafting. With personalized implants that give an optimal fit, it enables dentists to treat patients with increased precision, effectiveness, and speed. It makes tailored treatment choices possible. permitting brides to fabricate crowns and increasing the number of implants made according to patients' anatomical needs

Healthcare 3D printing Market size by Region 2022 to 2032: The 3D printing industry in the medical field in Europe is expected to grow to about USD 6.0 billion by 2032. The maturation in the three-dimensional print healthcare sector among regions will be aided by government support and an increase in research and development initiatives. Additionally, it is a hub for infrastructure innovation and improvement in the healthcare sector and a promising future for companies in the market.

Strategic Acquisition to Boost Industry Development: Cyfuse, Biomedical, Aprecia Pharmaceutical, Component Biosystem, Bio 3D technologies, BioBots, 3Dynamic Systems 3D bioprinting solution, 3DBiotek, and 3F Systems Inc. are a few of the topmost industries among worldwide healthcare three-dimensional prints.

Regulatory Issues with 3D Printer: Although there have been many efforts to scale up the technology, three-dimensional printing, particularly for personalized medicine, has grown in the procedure. Still in its infancy, though, is the technology. Furthermore, a variety of parameters influencing the precision, caliber, and security of computationally generated dosage forms need the use of the relevant regulatory requirements. Researchers can create medical gadgets with unique structures that are tailored to the needs of patients thanks to 3D printers. A new and distinct 3D application known as 3D printers has brought with it new regulatory issues. For instance, the beginning materials process parameters for SLS and FDM technologies tiny particle and ray beam for SLS, and threads and spray bed condition for FDM preclude comparisons between the two technologies.

While it controls 3D printed products, the USFDA is not in control of 3D printers. As of right now, there is no law governing production, quality control, and product design. However supervisory regulation the three-dimensional print is required, a variety of three-dimensional print processes makes it impossible to provide a single set of standards for all of them.

Furthermore, the distribution of 3D-printed pharmaceuticals may be hampered by legislation and development restrictions. Regulatory rules are vital for any growth process.

Some Points given below are Important to Incorporate into Regulatory Guidelines:

- ✓ Important standards for the printable of various components in pharmaceutical products
- ✓ The parameter for 3D technology is in process.
- ✓ Performance testing of 3D products
- ✓ Demonstrate the main feature of three-dimensional print intermediate such as three-dimensional inkjet, filament, substrate, as well as cartridge
- ✓ Finding the variables that affect a drug's release rate and route when it's 3D printed

Manufacturers can also play an important Role in Setting up Guidelines:

1. If the producer includes the production phases in the sequence diagram, regulatory agencies will be able to comprehend the process more quickly (3. Agreement and prospects in three-dimensional and Pharmaceutical [Internet]. U.S. Food and Drug Administration. 2020, n.d.)
2. The FDA has to keep up with 3D printer technology because it might one day help produce biological goods and pharmaceuticals that are tailored to each patient's needs.
3. It will be recommended that the organism design a new regulatory framework for ensuring the efficacy and safety of customized items.

TABLE 8: SOME COMMON MYTHS ABOUT 3D PRINTERS IN PUBLIC

This will be hazardous for the environment.	There is no environmental damage caused by the 3D printer. In the current environment, printing has the potential to be more environmentally friendly than the traditional approach of making more things as single-element products are readily recyclable and our tendency towards the usage of renewable and recycled materials is spreading,
The use of this technology helps people unemployed further.	Many in the sector fear that technological growth will lead to the loss of jobs; nonetheless, 3D printing has given certain qualified specialists access to new prospects. (De.kearney.com. 2021 [cited 5 January 2021], n.d.)
It is possible to deposit only one substance at a time.	Multiple materials may be utilized concurrently in different kinds of 3D printers. Compared to its single-material predecessors, multi-material 3D printers enable more intricate forms and patterns. For instance, a 3D printer released in 2019 is capable of simultaneously depositing eight distinct materials.
It is not a robust component.	This is true—a layer-composed component is often less rigid than a solid part—but it's false to say that all parts made using 3D printing are inherently weak. Larger layers or higher infilling in 3D printing increases sheet adherence and component toughness.
The demand for 3D printing doesn't seem very reliable.	The 3D printing market was valued at a CAGR (compound annual growth rate) of 29.48, the $13.7 billion in 2019 is expected to increase to $63.46 billion by 2025 percent between 2020 and 2025. More than half of consumers are interested in buying personalized goods and services, according to a recent study (Prnewswire.com. Retrieved 5 January 2021, n.d.)
This technology is novel.	Since the very initial 3D printer was released in 1987 and the concept was initially introduced in 1984, it is essentially outdated technology with a new name.

CONCLUSION: Owing to its outstanding versatility and effectiveness in developing and manufacturing new ways to deliver drugs for effectively obtaining better patient compliance, optimal drug absorption identities, better duration of shelf life and stability, and affordable and upon request patient-specific dosage forms, three dimensions print process had mixed as a novel, promising process among the pharmaceutical sector for developing drugs, formulation, and administration. Further manufacturing can completely transform the pharmaceutical industry by producing a wide range of form of administration with precise drug-excipient ratios. It has several benefits, including faster and more cost-effective production. Manufacturing has transformed thanks to 3D printing. For new goods, it shortens lead times and lowers tooling costs while improving design and production.

Because 3D printing technology is so flexible and effective at creating innovative medical goods, it holds enormous promise for medication discovery, formulation, and administration. Given its capacity to evaluate various release profiles, one of the primary benefits of 3DP technology as an option for designing and creating personalized medication is significant. Personalized medicine relies on the unique requirements of each patient to deliver safe and efficient care. Although the process of 3D printing is not in trend, it already shows a significant approach in creating customized medicine delivery systems. The successful base for 3D printing technology for the pharmaceutical business requires the resolution of several technological, quality control, and regulatory issues for pharmaceutical applications. There won't be any turning earlier it solved one time, manufacturing pharmaceuticals embrace and utilize this technology to its full potential.

It is expected that technology for 3D printing is going to have a bright future. With it, the healthcare system might undergo a transformation and personalized treatment could lead to a smart future. Soon, a variety of innovative dosage forms will be produced with three-dimensional processes. Overall, the pharmaceutical industry is paying close attention to the 3D printing process for research and development. However, real progress in this sector won't be made unless innovative, ornamented three-dimensional administration forms are produced in manufacturing process. Before the manufacture of 3D-printed goods on demand in a healthcare environment is possible, however, additional study in the field is required to understand how process factors affect the printing outcome and how to increase 3DP repeatability. The versatility of 3D printed goods and the many production benefits that 3DP provides mean that more 3DP may get past the proof of idea phase and become a widely utilized manufacturing tool if research in the field of 3DP continues to grow. The US FDA released guidance on technical aspects for additively made medical devices employing 3DP technologies making realises to hasten the use of the process. As a result, we anticipate seeing an increase in the number of pharmaceutical and medical items on the market that are 3D printed in the next years. Thus, the development of personalized medications and systems for delivering drugs may be made possible by 3D printing technology, which may also result in other noteworthy advancements in the fields of medicine and healthcare.

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