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Review Paper

3D Printed Tablets for Oral Dosage Forms: Based on Types, Technologies, Application in Various Diseases with Examples

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ABSTRACT

Three-dimenstional (3D) printing, also known as cumulative manufacturing, has surfaced as a transformative technology in the pharmaceutical assiduity, offering a paradigm shift from traditional mass product toward substantiated pharmacotherapy. This review totally explores the elaboration of 3D printing for oral lozenge forms, fastening on the literature published between 2019 and 2024. The primary advantage of this technology lies in its capability to customize drug by acclimatizing the size, shape, medicine release profile, and cure revision to meet specific case requirements.While 3D printing offers unknown openings for customization, the structural integrity and mechanical parcels similar as hardness and frangibility of the published tablets remain critical challenges. This paper discusses the colorful factors impacting these mechanical parcels, including the selection of specific excipients and the optimization of publishing parameters. Likewise, the review addresses the current nonsupervisory geography, noting the absence of specific guidelines for 3D- published solid oral lozenge forms and the posterior need for new nonsupervisory fabrics to ensure quality norms. Computational styles and expansive pre-and post-processing evaluations are stressed as essential tools for maintaining quality control. By synthesizing data from 500 recent publications, this review provides a comprehensive overview of the current approaches, specialized challenges, and the unborn outlook for integrating 3D-published tablets into clinical practice.

INTRODUCTION

3D printing (3DP), or cumulative manu76facturing, is revolutionizing oral medicine delivery by enabling the subcaste-by-subcaste fabrication of customizable, patient-centric lozenge forms. Unlike traditional mass manufacturing, 3DP allows precise control over medicine lading, figure, and release biographies, offering results for individualized drug and

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complex release patterns. 3D printing creates 3D objects from CAD models, moving from prototyping to artificial, precise, and decentralized pharmaceutical product. Interest in three-dimentional (3D) printing has grown significantly called a new "artificial revolution" because they've the eventually to transfigure indeed well-established requests. When the FDA approved Spritam the first 3D-published drug in 2015, numerous anticipated the technology to take over the pharmaceutical assiduity snappily. Still, despite a massive increase in scientific exploration, on other 3D-published medicines have been approved by the FDA or the European Commission since also. That said, the assiduity is still moving forward. For illustration, a company called Triastek has entered concurrence to begin clinical trials (IND concurrence) for four different 3D-published products in the United States. While Spritam uses a system called ZipDose, Triasatek uses an "fashion. Indeed though these styles are different, they've both considered types of 3D printing.

3D printing technologies all partake a common process they use digital data to define the exact position of every part of an object using 3D equals. Generally, a product is designed on a computer (CAD), and also the machine builds it subcaste by subcaste grounded on that digital plan. This system allows for incredibly precise control over how accoutrements are arranged. In traditional manufacturing, constituents are generally mixed into a invariant mix to insure the cure is correct. 3D printing, still, allows for unique shapes and internal structures. This can be used to control how a medicine is released or to keep different constituents in separate chambers within a single pill. Recently, experiments have started agitating 4D printing. The "fourth dimension" in these products is time. This means the 3D-published object is designed to change its shape or geste over time, frequently touched off by effects like temperature or humidity (known as "shape memory goods"). The thing of this review is to give you an overview of the most recent developments in 3D-published medicines, their ways and operation in colorful conditions with their phrasings.

HISTORY

YEAR	Milestone	Printing Technology	Important Advances
1996	Initial Release	Desktop 3D Printer	Solid samples made of PCL and PEO polymers with blue and yellow dyes showed intricate drug delivery systems.
2000	Initial prototypes	BJ/Droplet Binding	Formulations of diclofenac and chlorpheniramine utilizing methacrylate copolymers are examples of early research into binding powder beds with liquid.
2012	The laser SLS Sintering	SLS	Initial application of PCL-based selective laser sintering for progesterone pills.
2014	Extrusion Era	FDM/SSE	For complicated bilayer tablets, research turned to semi-solid extrusion and fused deposition modeling (PVA filaments).
2015	FDA Approval	ZipDose (Jetting Binder)	Aprecia's Spritam (levetiracetam) The US FDA authorized pharmaceuticals as the first 3D printed medication.
2016-19	Polypills & Designs	SLA, SLS, FDM	creation of "polypills" with five or six distinct APIs in distinct sections with pediatric-specific forms like teddy bears.

2020+	Next Gen Technology	Multi-Material/4D	Investigation of 4D printing (time-responsive forms) and IND approval for a number of new Triastek 3D-printed goods.

3D PRINTED TABLETS

3D published tablets (or "printlets") are oral solid lozenge forms manufactured on-demand using cumulative manufacturing (subcaste-by-subcaste deposit) rather than traditional contraction. This fashion allows for largely individualized drug through precise control over medicine lozenge, complex shapes, and controlled-released biographies, frequently combining multiple specifics into one pill. The first 3D-published tablet, Spritam (levetiracetam), was approved for epilepsy, showcasing its eventuality for high medicine lading.

ADVANTAGES

- Quicker pre-medical assessment of new medicines

3D printing has given druggists and medical masterminds the capability to customized medicines by modifying the design straight to its CAD train. In this way, duplications can be made more snappily. These duplications are also a lot cheaper than the traditional way of manufacturing medicines. For case, tweaks or adaptations in the excipients, swap forms and tablets of the drugs can be made fluently.

- Chance for Personalized Drug

For cases with multiple conditions, a 3D published lozenge similar as a "polypill" can be used. Polypill contains multiple active constituents that are combined into a single lozenge. This is used to treat different diseases. Some capsules are also designed to treat the complaint of some particular case. Still, the case's age, weight or organ function must also be considered.

- New phrasings for bettered medicine

With the conventional system of producing drugs, some capsules are delicate to swallow. But with 3D printing, capsules can be designed according to a case's preferences. For illustration, medical masterminds can produce a lozenge that can disintegrate fleetly in a case's mouth therefore, making it easier to take. Spritam First 3D published medicine. In 2015, Aprecia was the first pharmaceutical brand to use 3D printing technology to produce a medicine called Spritam. This medicine is meant to treat symptoms of epilepsy similar as a onset seizures and myoclonic seizures. When it was released, Spritam also entered then necessary US FDA blessing. The medicine has a unique structure that dissolves significantly faster than the average lozenge.

- On-demand medicinal manufacturing

3D printing allows apothecaries and healthcare providers to print drugs on-demand rather of mass producing them. In this way, the medicinal diligence can revolutions the force chain. Thus, lowering distribution costs.

DISADVANTAGES

- Product liability threat

With 3D printing, pharmaceutical companies can authorise their arrangements to apothecaries and healthcare providers. Therefore, they can now fluently publish medicines locally. However, pharmaceutical companies cannot conceivably oversee the effectiveness of every 3D printing operation. Also, they need to consider the implicit product liability implications. According to the pharmaceutical companies part in furnishing their product design, they maybe incompletely responsible for any undesirable incidents or product disfigurement claims. Other parties involved similar as the printer manufacturer may also be liable for this fallout. For medicinal companies who are planning to venture into 3D printing, they should develop a policy for certifying their arrangements. In this way, they

will ensure that they're financially and fairly defended.

- Cyber threat

The rapid-fire increase in reproducing fake capsules is one of the topmost enterprises with 3D printing. Likewise, 3D printers are now being used by hackers to produce fake drugs briskly than the traditional manufacturing method. As an illustration, hackers who gain access to a drug's design can mass-produce the medicine overseas. This can exploit the intellectual property of the pharmaceutical company. Also, if the medicine is inaptly produced, it can beget detriment to the cases. Therefore, hitting the pharmaceutical company's character and fiscal status. Apart from that, hackers can also make variations to the drug's constituents or boluses. This may lead to severe health consequences for the cases.

- Safety and effectiveness of 3D printers

The traditional way of mass-producing drugs is subject to violent supervision from authorized agencies similar as FDA. This guarantees the company and the consumers that the products are manufactured carefully. However, with 3D printing, the FDA cannot regulate every printing operation. Therefore, determining how the product is developed may be questioned. Likewise, with 3D printing, there's still a possibility of imperfect 3D printer and gratuitous printing failures.

TECHNIQUES OF 3D PRINTED TABLETS

Colorful technologies have been developed for the construction of 3D published tablets. Despite individual differences, the process involves three introductory way that are common to all ways

a. The creation of a computer-backed design train
b. The conversion of the train CAD into a rapid-fire prototyping stereolithography train that describes the face figure of the 3D object.
c. Its conversion into a machine-specific law. (gcode) that's honored by the 3D publishing machine and produces the final object.

Some of the most common 3D printing ways used in the pharmaceutical assiduity for the product of solid oral lozenge forms are

1. Binder Jetting
2. Fused Deposit Modeling
3. Semi-Solid Extrusion
4. Picky Ray Sintering
5. Stereolithography

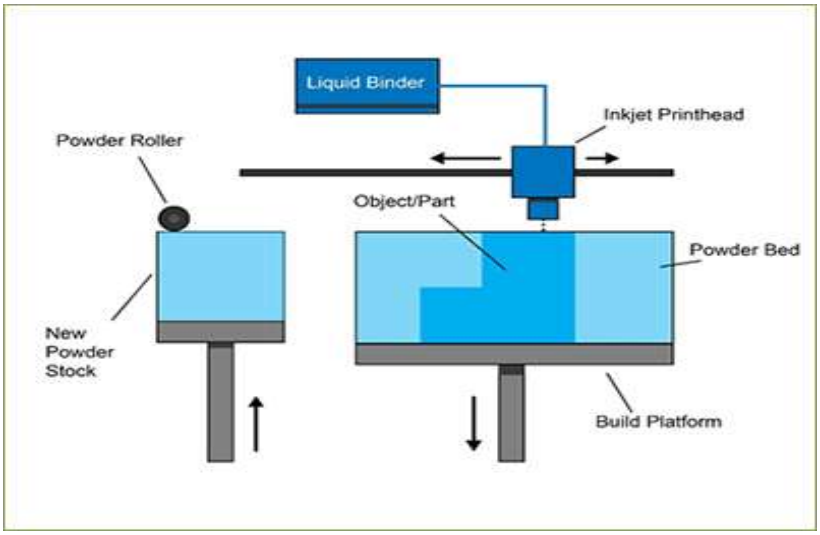
1. Binder Jetting

Binder Jetting (BJ) is a 3D printing fashion in which a liquid binder result is precisely applied to a greasepaint substrate using a printer snoot.

The bedewed greasepaint patches are also fused together, solidifying the subcaste. The first subcaste is published onto the figure platform, also the plunger lowers to the consistence of the following subcaste and posterior layers are published and clicked together. The process is repeated several times until the 3D object is produced.

The BJ offers important advantages for the product of pharmaceutical lozenge forms. The molding process takes place at room temperature and atmosphere, avoiding oxidation and thermal declination of active constituents. Also, it's applicable to a wide range of accoutrements and produces largely previous tablets with high medicine ladings. Thus, it's most suitable for the medication of immediate release, fast dissolving, or dispersible lozenge forms. Still, one the major downsides is that it's a multi-step process taking post-processing way similar as drying. It's particularly grueling to produce tablets with acceptable mechanical parcels due to high porosity. It's supported that excipient, and especially binders, play a significant part in the physical parcels of tablets. Paddings with high water solubility, humectants with high water

content and binders with high density in result can increase the hardness and list strength of tablets, and accordingly protract their decomposition time.



Principle

Binder Jetting 3D Printing (BJ-3DP) has surfaced as the leading cumulative manufacturing fashion for pharmaceutical product. The process operates on a cyclical, subcaste-by-subcaste base to make solid lozenge forms.

The Printing Process

The abecedarian medium of BJ-3DP involves the following way

1) Greasepaint Spreading A comber distributes a livery, thin subcaste of greasepaint onto the figure platform.
2) Picky List A mobile printhead moves across the platform, scattering liquid driblets that act as a "cement" to widely bind the greasepaint patches together in a specific pattern.
3) Subcaste Progression The platform lowers slightly, and the comber applies the entire structure is formed.
4) Post-Processing Once the printings is finished, the objects are removed from the greasepaint bed. Redundant loose greasepaint is cleared down, and the final medications suffer post-processing to insure stability and quality.

Expression Inflexibility

The distribution of the Active Pharmaceutical component (API) can vary depending on the asked outgrowth

Binder- Only Essay The essay contains only the binding agent, while the API and other excipients (inactive constituents) arepre-mixed into the greasepaint bed.

API- Invested Essay The API is dissolved or suspended as nanoparticles within the liquid essay and scattered directly onto a bed of excipients.

Handling undoable medicine.

While BJ-3DP is naturally suited for water-answerable medicines, it can also accommodate undoable APIs through specialized pretreatment. Current exploration in this area is limited but promising. For case, experimenters have successfully used spray drying to combine hydrophobic (water-stewing) medicines like clotrimazole with hydrophilic (water-loving) carriers like PVP and lactose. This process significantly improves the medicine's wettability, making it much easier to publish and further effective when consumed.

a. Advantages of Binder Jetting Fashion

2. High Speed & product rate the subcaste-wide print head enables briskly publishing than numerous other ways, making it ideal for high-volume, industrialized product.
3. No Support Structures The girding loose greasepaint acts as a natural support, allowing for complex shapes and reducing material waste.
4. Wide Material Versatility Able of publishing with essence, pottery, beach, and beach-casting molds.
5. Cost-Effective generally lower cost per part compared to other essence cumulative technologies.
6. Low Residual Stress Because it generally operates without high heat during the figure process, corridor parade minimum thermal screwing.
7. Large figure Size Suitable for producing large-scale corridor or high-volume batches.

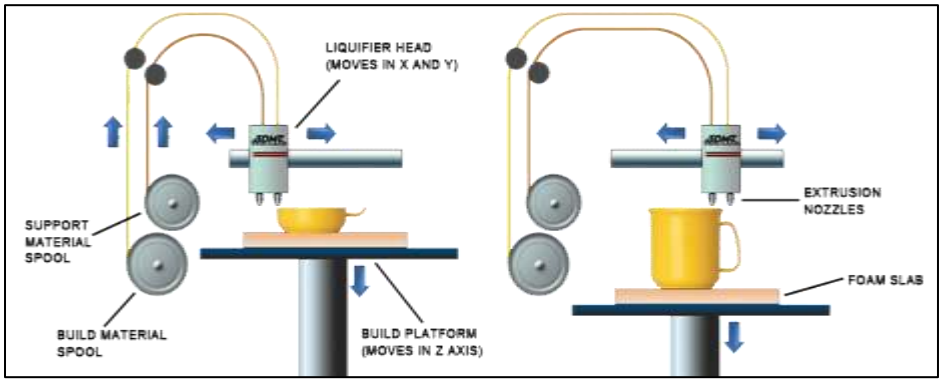
Disadvantages of Binder Jetting Fashion

1. Ferocious Post-Processing corridor are published as "green corridor" and bear curing, sintering, or infiltration to gain strength, adding to total product time and cost.
2. High Porosity and Lower Strength Without optimal sintering, corridor can be relatively pervious and weaker than those made with other styles.
3. Dimensional delicacy & Loss Post-Processing, specifically sintering, can lead to significant, frequently hard-to-prognosticate, loss of corridor.
4. Surface Finish While good, it may not match the resolution of advanced-end styles and can have a rough face finish, though it can be meliorated.
5. Material Constraints While protean, some specific accoutrements may struggle to reach asked viscosity.
6. Safety Hazards The process uses OK, frequently dangerous maquillages, challenging proper environmental controls and safety outfit.

2. Fused Deposit Modelling

In fused deposit modelling (FDM), medicine-loaded thermoplastic polymer fibers are extruded through the print head at a specific temperature in specific directions. The molten hair is also deposited onto the figure plate and solidifies in consecutive layers to form the object.

Originally, the operation of this technology was established for non- pharmaceutical purposes, substantially in aerospace, armature, and automotive diligence due to the lack of pharmaceutical grade polymers. Still, expansive testing has been carried out over the times and moment, there are a variety of polymers that can be used as matrices for medicines in FDM 3D printing. Ethyl cellulose (EC), hydroxypropyl cellulose (HPC), hydroxypropyl methyl cellulose (HPMC), hydroxypropyl methyl cellulose acetate succinate (HPMCAS), ethylated acrylate copolymer (Eudragit RL and RS), polyethylene glycol (cut), polyethylene oxide (PEO), polylactic acid (PLA), polyvinyl alcohol (PVA), and polyvinyl pyrrolidone (PVP) are the most generally used polymers according to the current literature.



Principle

Fused Deposit Modeling (FDM) depends heavily on the physicochemical parcels of the hair- specifically its mechanical, thermal, and rheological (inflow) characteristics. These factors determine whether a material is "printable" and how well the final product will hold its shape.

1) Material Selection and Thermoplastics

To be used in FDM, a polymer must be thermoplastic, meaning it softens when hotted and hardens when cooled. Common artificial accountments include ABS (acrylonitrile Butadiene Styrene), PLA (Polylactic Acid) Polyamide and Polycarbonate In the medical field, Polyvinyl Alcohol (PVA)- traditionally used only as a dissolvable support material is gaining traction for individualized drug because it can be reused into a colloidal result.

2) Thermal Stability

Two critical temperatures define a polymer's geste the Glass Transition Temperature (T_g) and the Melting Temperature(T_m). The Safety Gap A polymer's T_g should be significantly lower than its declination temperature to help the material from breaking down during the heating process. The Printing Threshold exploration suggests that for unformed polymers, the minimal printing temperature is roughly T_g 78 textbook {°C}.

3) Rheology and Viscosity

Rheology refers to how the hair flows under stress. Density is a crucial part of this, impacting two stages of printing Extrusion How fluently the melted hair passes through the narrow snoot. Structural Recovery How snappily the material "sets" and regains its solid structure after being deposited. Factors Affecting density

Internal The chemical expression, the molecular weight of the medicine being used, and the solid form of the material. External The extrusion temperature, the speed of the print, and the periphery of the snoot.

4) Hair thickness

Eventually, the hair must be fully homogeneous. Any internal excrescencies similar as air bubbles or lumps- will beget variations in the consistence of the published layers, leading to structural failures in the final lozenge form.

Advantages of FDM

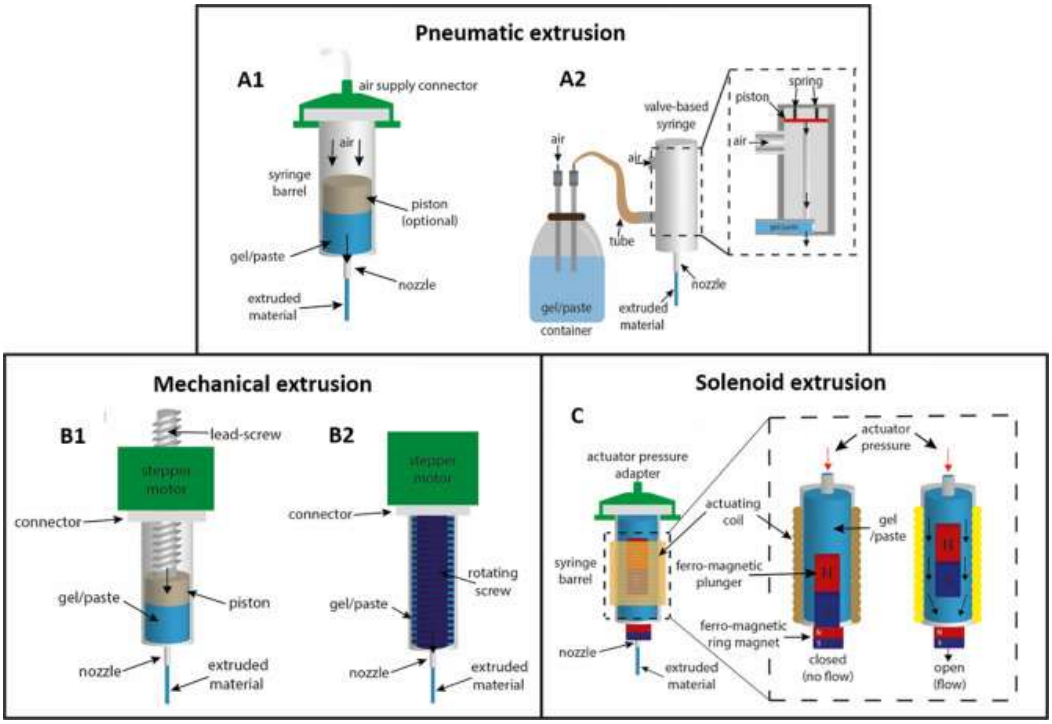
- Low Cost FDM machines and accoutrements (fibers) are affordable , making it accessible for rapid-fire prototyping.
- Material Variety Supports a broad range of thermoplastics (PLA, ABS, PETG, TPU) acclimatized for strength, inflexibilty, or environmental requirements.
- Ease of Use Considered one of the easiest 3D printing technologies to learn, maintain, and operate, according to Scripd.
- Scalability Printers can fluently produce large models and offer large figure volumes.
- Good for Prototyping Ideal for quick, functional, and conception prototyping.

Disadvantages of FDM

- Low Resolution Layers are frequently visible, performing in lower face quality and reduced delicacy compared to SLA/SLS, as mentioned by MadeInAdd.
- Structural Weakness Anisotropic characteristics mean corridor are weaker along the Z-axis (subcaste lines).
- Slow Speed High- detail, large corridor take a long time to publish.
- Support needed Complex, overhanging corridor bear support structures, which can damage the face finish upon junking.
- Limited delicacy Lower perfection in detailed, fine-point shapes.

3. Semi-Solid Extrusion

Semi-solid extrusion (SSE) is a 3D printing fashion in which material in semi-solid or semi-molten form is extruded from a hype-suchlike system in consecutive layers to form a three-dimensional object. Unlike FDM, which uses solid fibers, SSE prepares the starting material by mixing the ideal rate of active substances with detergents to form a gel or paste. Also, low temperatures are used during the process, thus, it's suitable for thermolabile active constituents. It has been applied to the medication of colorful lozenge forms including immediate release tablets, or dispersible tablets, pediatric gum formulations, controlled release tablets, gastro- floating tablets, and solid lipid tablets. It's a protean and simple fashion as the medicine can be mixed directly with excipients and filled into a hype or catridge. Thus, it can potentially be used in clinical practice, in original apothecaries or conventions, to produce customized and substantiated phrasings.



Principle

Extrusion- grounded 3D printing systems for medicine and bioinks generally use one of three main driving mechanisms. Each system has distinct advantages depending on the material's consistence (density)and the needed perfection.

1) Curvaceous- Grounded Systems

These systems use compressed air to push circumfluous accoutrements through a snoot.

Versatility They're largely adaptable, able of handling both low- and high-density accoutrements.

2) Mechanically Grounded Systems

Mechanical systems apply direct physical force to the hype and are generally divided into piston-driven or screw-driven designs. Effectiveness They're frequently simpler, more affordable, and easier to transport because they don't bear a big air compressor. Workflow These systems allow for faster hype changes during a print, which can significantly ameliroate overall product effectiveness.

3) Electromagnetic Drive Systems

This system uses electrical beats to spark a stopcock located at the base of the hype. Medium it's designed to work with specific "cross-linking" styles, similar as accoutrements that solidify when exposed to ions or UV light. Constraint While largely precise for thin, low-density bio-inks, it's generally not suitable for thick or high-density accoutrements.

Advantages of Semi-Solid Extrusion (SSE)

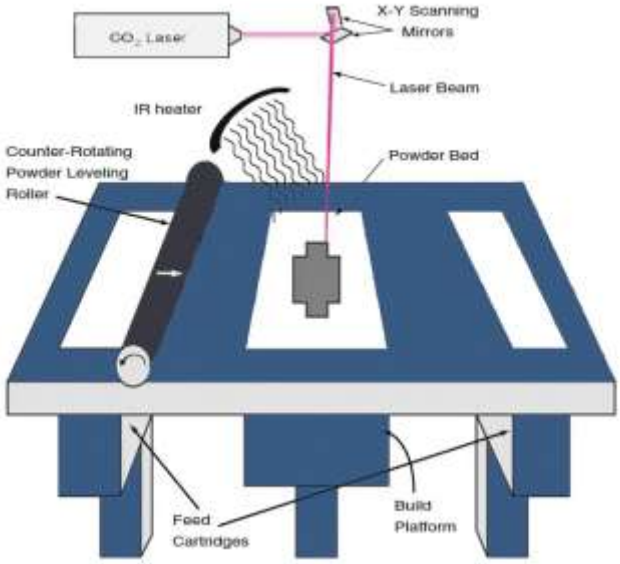
- Low-Temperature Processing Ideal for heat-sensitive medicines, biologics, and bioelectronics, as it doesn't bear high heat to melt accoutrements.
- Wide Material Versatility can use a broad range of excipients, including hydrogels, polymers, pastes, and food products.
- High medicine lading & individualized Dosing Able of incorporating high attention of active constituents, making it ideal for substantiated drugs (e.g., pediatric or senior tablets).
- No Support Material demanded the structural integrity of the pastes allows for erecting complex, freestanding 3D shapes.
- Simplified Manufacturing Uses simple, frequently low-cost, hype-grounded systems.

Disadvantages of Semi-Solid Extrusion (SSE)

- Slow product pets frequently slower than traditional manufacturing or other 3D printing ways (like FDM).
- Formulation Dependence The printing quality is heavily dependent on the rheological parcels (density, inflow geste) of the paste.
- Long Post-Processing Time published products frequently bear a drying or solidification step, which can be time consuming.
- Scalability Issues Primarily used for R&D or substantiated drug rather than high-outturn artificial product, although this is changing.
- Lack of Standardization There's a lack of nonsupervisory frame and standardized quality controls, making it delicate to optimize and validate processes.

4. Picky Ray Sintering

Picky ray sintering (SLS) is a 3D printing process that uses a greasepaint bed as the starting material, analogous to BJ. Still, the main difference between these two ways is that SLS uses a ray to toast and fuse the greasepaint patches together, rather than using a liquid binder result. During the printing process, the first subcaste of greasepaint is spread unevenly on the figure platform and also the ray draws a specific pattern on the face of the greasepaint bed. Once the first subcaste is completed, a comber spreads a new subcaste of greasepaint on top of the former one, and as the process continues, a 3D object is gradationally formed. SLS is a one-step process that doesn't bear previous medication of fibers as in FDM or post-processing way such as Drying in BJ and SSE.



Principle

The core principle of Picky Ray Sintering (SLS) is grounded on the thermal emulsion of powdered accoutrements through a process called greasepaint bed emulsion. Unlike traditional manufacturing that removes material, SLS builds structures subcaste-by-subcaste by precisely applying a high-power ray to a bed of fine-granulated greasepaint. The process begins by hotting the entire figure chamber to a temperature just below the melting point of the specific polymer or pharmaceutical mix being used, which reduces the quantum of ray energy needed to bond the patches and prevents thermal screwing.

A thin, invariant subcaste of greasepaint is spread across the figure platform, and the ray also traces the specific cross-sectional figure of the 3D model onto this face. This localized heat causes the greasepaint patches to fuse at their contact points a process known as sintering without reaching a completely liquid state. Once a single subcaste is solidified, the figure platform lowers by a bit of a millimeter, and a new subcaste of fresh greasepaint is deposited over the former bone. The ray also repeats its path, contemporaneously fusing the new patches together and relating them to the subcaste below. A unique advantage of this principle is that the girding unsintered greasepaint remains in place during the figure, acting as a natural support medium that allows for the creation of largely complex internal infrastructures, similar as pervious structures or concave chambers, which are frequently employed in ultramodern medicine delivery exploration to customize the release rate of drug.

Advantages of Picky Ray Sintering

- No Support Structures needed Because the girding unsintered greasepaint supports the part, complex designs, overhanging features, and interlocking corridor can be published without supports.
- High Design Freedom & Complexity Allows for the creation of intricate, concave, and complex internal structures that are insolvable with other styles.
- Isotropic Strength SLS corridor have nearly equal strength in all directions, making them ideal for functional, durable prototypes and end-use products.
- Cost-Effective Small Batches Ideal for low-volume product and rapid-fire prototyping as it eliminates the need for precious tooling or molds.

- High product Speed Multiple corridor can be "nested" within the figure volume to maximize effectiveness.

Disadvantages of Picky Ray Sintering

- High Cost of outfit SLS printers and accoutrements are precious, and conservation is high.
- Surface Finish and Accuracy Parts frequently have a coarse, pervious face finish that requires post-processing (sanding oil, or vapor smoothing) for a smooth finish.
- Loss and Warping The heating and cooling process can lead to thermal distortion (screwing) and loss, especially on large, flat shells.
- Safety and Post-Processing

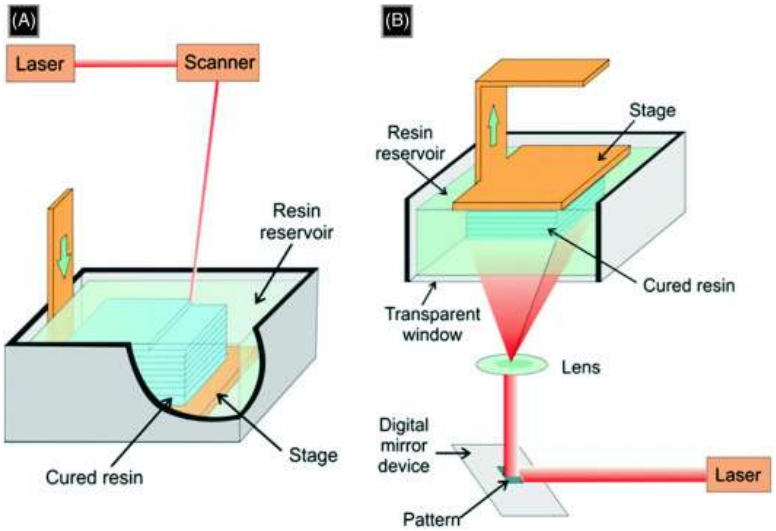
The process requires professed drivers to handle greasepaint, and drawing the finished corridor is time- consuming.

- Limited Accoutrements While important, the material options are generally confined to thermoplastics, particularly nylon.

5. Stereolithography

Stereolithography (SLA) is an cumulative manufacturing process in which the object is created by widely curing a polymer resin subcaste by subcaste with an ultraviolet (UV) ray. The accoutrements used in SLA are photosensitive polymers that are in liquid form. In some cases, post-curing with a UV roaster can be used to increase the mechanical strength of the object. In the medical field, stereolithographic 3D printing is substantially used in towel engineering and in the fabrication of implantable bias. still, operations in the pharmaceutical field are still limited.

One of the major advantages of this fashion is the high printing resolution, which is superior to other 3D printing ways. It also minimizes original heating during the process, making it suitable for the fabrication of oral lozenge forms containing thermolabile medicines. This was experimentally demonstrated by Wang et al. Who successfully used SLA to publish tablets containing 4- ASA, a known thermosensitive medicine. It was set up that SLA reduced thermal medicine declination compared to FDM. Still, the main reason holding back the operation of SLA in medicines is the limited number of photo cross linkable polymers that are safe for pharmaceutical use.



Principle

In light- grounded 3D printing, the process of photopolymerization is used to transfigure liquid resins into solid structures. This chemical chain response requires three essential factors a light

source, a monomer or oligomer (the structure blocks), and a photo initiator (PI).

The Medium of Action

The process begins when the light source emits photons that strike the photo initiator. This triggers a response that produces" initiating substances" generally free revolutionaries, anions, or cations. These largely reactive patches also attack the near monomers or oligomers, forcing them to bond together.

Two Types of Light Curing

Depending on how the motes bond, the curing process is distributed into two distinct types

print- convinced Polymerization A chain response where monomers are added one by one in a direct fashion, forming long molecular chains.

print- crosslinking A process where chemical bonds (crosslinks) are formed between being macromolecular chains, creating a sturdy, connected network.

Advantages of Stereolithography

- High Accuracy and Detail Produces extremely smooth shells and fine details with forbearance as tight as 0.05 mm.
- Smooth Surface Finish SLA corridor frequently act finished products, taking minimum sanding or polishing, making them ideal for visual models.
- Speed Fast, effective, and able of producing functional corridor within a day.
- Versatility Able of producing complex, intricate shapes that other ways can not, including flexible and rigid objects.
- Low- cost Prototypes Cost-effective for creating detailed prototypes.

Disadvantages of Stereolithography

• Expansive Post-Processing Parts bear washing with detergents (e.g., IPA), support junking, and post-curing in a UV roaster.

• Material Limitations Limited material options compared to FDM or SLS, with resins frequently being more precious.

• Fragility and UV perceptivity published corridor can be brittle and prone to yellowing or declination over time when exposed to sun.

• Support Structures obligatory supports can leave marks and circumscribe design freedom.

• lower figure Volume Industrial SLA machines can be precious, and consumer- grade machines are frequently limited to lower figure sizes.

• Long- term Stability Not suitable for long- term out-of-door use due to UV perceptivity.

Examples Of 3D Printed Tablets :

Spritam ®(Levetiracetam) The first FDA-approved 3D- published medicine (2015), exercising binder jetting to produce largely pervious, fleetly disintegrating tablets for epilepsy.

• **Triastek** T19 & T22 MED ™ (Melt Extrusion Deposition) published tablets designed for timed, point-specific release in rheumatoid arthritis.

• **Polypills** (Multi-Active Tablets) Custom-designed tablets containing multiple active constituents (e.g., nifedipine, captopril, glipizide) for technical release biographies;

• Individualized ODTs (Orally Disintegrating Tablets) Acetaminophen tablets published with complex shapes (e.g., QR canons) using binder jetting for personalized dosing.

• FDM- published Core- Shell Tablets Sustained-release phrasings for psychiatric specifics, using polymers like Eudragit or PVA to control medicine release.

❖ Application Of 3D Printed Drugs In Various Disease Condition

Diabetes mellitus (DM)

Diabetes Mellitus is considered one of the most common habitual metabolic diseases characterized by elevated blood sugar situations in the body due to endless damage to beta cells (Type 1 DM) or

stashing of shy or imperfect insulin by beta cells with a attendant drop in insulin perceptivity in apkins (Type 2 DM). The primary cause of DM can depend on a cornucopia of factors ranging from inheritable and environmental factors to ethnical factors. In recent times environmental factors and ethnical factors are also taken as consideration for cause of DM.

In recent times, 3D published polypills have been fabricated to synopsize 2 or 3 pharmaceutical actives in 1 lozenge, thereby reducing HBA1c situations, with a drop in the dosing frequence. triadic oral remedy is a treatment authority that employs a drug that is combined with two unsuccessful combinations of medicines in a polypill that results in a drop in the glycemic indicator and HbA1c, as reported by the TrIED study. A combination lozenge containing glimepiride, metformin, and pioglitazone (GMP) was administered along with a combination of slow- release metformin and 70/30 mortal insulin both doubly daily (BD), which eased the reduction of HBA1c situations in Type 2 diabetic cases.

• Cardiovascular conditions (CVD)

Cardiovascular Disease (CVD) is a general term used to describe the conditions that affect the heart or blood vessels. They include cardiac arrest, coronary heart complaint, heart failure, hypertension, arrhythmia, supplemental roadway complaint, natural heart complaint, deep tone thrombosis, and pulmonary embolism.

Fixed cure combinations (FDC) were set up to be an effective system of adding patient adherence and antihypertensive efficacity. still, FDC rules are aimed at the general public and thus can not be flexibly specified, depending on the requirements of small groups of cases. In this case, 3D published poly capsules can help achieve these flexible doses. The study by “Pereira et al”. shows a significant enhancement of» 44 in adherence to drug in CVD cases when treated with custom 3D published poly capsules, compared to conventional treatment. Case adherence putatively decreases with an increase in the number of specifics. FDM 3D printed was used for the construction of polypills conforming of amlodipine besylate, indapamide, lisinopril dihydrate, and rosuvastatin calcium using polyvinyl alcohol as polymer.

❖ **3D- Published Cancer Specifics Medication:**

APIs (Active Pharmaceutical Ingredients)	Dosage Form	Printing Method	Material/ Excipients	Specific Disease
5- fluorouracil	Tablet	Printing with a binder jet.	Polyethylene glycol (PEG); Soluplus® (SOL)	Cancer
5-fluorouracil; Cisplatin	Tablet with two layers	Micro syringe with pressure assistance	Triethyl citrate with poly (lactic-co-glycolic acid) (PLGA)	Cancer of the liver
Doxorubicin	Absorber	Constant Liquid Interface Production (CLIP)	Polystyrene sulfonate	Cancer
Paclitaxel; Lidocaine with Rapamycin	Tablet with many layers	3D printing using extrusion	polylactic-co-glycolic acid (PLGA)	Cancer

❖ **Additional Medical Conditions:**

APIs	Dosage Form	Printing Technique	Illness Situation
Metformin; tablet of glimepiride bilayer	Bilayer tablet	Fused Deposition Modelling	Diabetes
Metformin	Tablets	Fused Deposition Modelling	Diabetes
Metformin	Gummies	Extrusion that is semi-solid	Diabetes
Dapagliflozin	Tablet/Paste	Pressure that is semi-solid PAM (assisted micro syringe) extrusion-based 3D printing Diabetes	Diabetes
Glipizide	The Duo Tablet is a tablet that is integrated into a bigger tablet.	Fused Deposition Modelling	Diabetes
Aspirin, hydrochlorothiazide, Atenolol; Pravastatin; Ramipril	Tablet with many layers	3D printing using extrusion	High blood pressure; Dyslipidemia
Glipizide, Nifedipine, and Captopril	Tablet with many layers	3D printing using extrusion	Diabetes and Hypertension
Hydrochlorothiazide with Enalapril	Tablet with two layers	Fused Deposition Modelling	High blood pressure
Lisinopril Spironolactone	Tablet with many layers	3D printing using binder jetting	High blood pressure

CONCLUSION

3D printing technologies all partake a common process they use digital data to define the exact

position of every part of an object using 3D equals. generally, a product is designed on a computer (CAD), and also the machine builds it subcaste by subcaste grounded on that digital plan. This system allows for incredibly precise control over how accoutrements are arranged. In traditional manufacturing, constituents are generally mixed into a invariant mix to ensure the cure is correct. 3D printing, still, allows for unique shapes and internal structures. This can be used to control how a medicine is released or to keep different constituents in separate chambers within a single lozenge.Overall, this review aims at reflecting the current development status, artificial characteristics, and overall development trends of 3D- published medicines. We hope that this review can give a meaningful reference for those who are engaged in affiliated exploration. It's believed that with nonstop sweats, the future of the 3D-published medicine assiduity is promising and will clearly promote medicine medication technology that's intelligent and substantiated.

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