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Review article on 3d printing of drug manufacturing

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ABSTRACT :

In 2015 three- dimensional 3D published medicine was first approved by the food and medicine administration in that there are multiple ways used in the pharmaceutical field for developed the 3D medicine patch Streolithography, Binder deposit, picky ray sintering, fit printing, extrusion- grounded printing, hot melt extrusion, Fused deposit.This ways used in developing the 3D medicine patch with their specific operation this fashion which are compatible with printing of medicine product, to both polymer hair and hydrogels as a carrier medicine. By using 3D printing technology it can publish tablet with specific arrangement of shape and structure which control the release and distribution of cells. Three- dimensional printing(3DP) allows for the development of a broad variety of figure by computer- backed design and the use of colorful ways and accoutrements. This technology will reform the medicinal manufacturing style and manufacturing fashion published subcaste by subcaste to form Construction of 3D object grounded onpre-design 3D digital model with the help of computer backed software.Three dimentional (3D) printing is an cumulative system, the consecutive subcaste of material are deposited or solidified to form a 3D patch of medicine. lately, the FDA has approved 3D published tablet called SPRITAM. when we compared traditional process and 3D printing of medicine development we can see that the 3D printing has lesser advantages over the traditional process.3 D printing is called an cumulative manufacturing, was developed by scientist Charles housing in early 1980s. For below reasons, 3D printing for medicine manufacturing is the future of pharmaceuticals. In this review to refocused the challenges and unborn compass of 3D printing of medicine manufacturing in pharmaceutical assiduity.

Keywords: stereolithography, thermal inkjet, binder deposition, inkjet printing, fused deposition.

INTODUCTION

Prolusion

3D printing also called accretive manufacturing was first developed by architect Charles Hull in the early 1980s. Three- Dimensional Printing is now one of the most swiftly evolving branches of technology, art, and wisdom, with a wide range of applications.after getting successful blessing from food and drug administration the first 3D published drug manufactured in 2015, so after the 2015 interest in 3D printing of pharmaceutical product has been growing. presently the 3D printing technologies applied in the pharmaceutical drug field mainly include fused deposit (FD), stereo lithography (SL) and binder extrusion printing fit printing, picky shaft sintering binder deposit etc.

The most studied is fused deposit modelling (FDM), an extrusion- predicated 3D- printing fashion, in which polymeric filaments are melted, extruded through a snoot, and also resolidified upon contact with the cool print bed. picky shaft sintering is the most analogous system to the common drug manufacturing process of cream pressing, in that it relies on loose cream that becomes collected into a solid object. Binder deposit, which involves publishing a liquid list affect into a cream bed, is another cream- predicated fashion. Stereolithography is a fashion for extensively solidifying a bed of photosensitive material that can also be used to make drugs. Inkjet publishing offers high resolution.

3D printing has great advantages over traditional process in producing largely complex and custom- designed products so it's farther provident and time-saving. Three dimensional printing(3DP) technology is a new fashion for rapid-fire- fire prototyping, which construct the solid object by deposit of several caste in sequence. drug delivery proposition has advanced over time, from immediate- release oral capsule forms to targeted- release specifics. Three-dimensional(3D) printing technology has been used to produce a range of drug delivery systems, including oral controlled release systems, micro capsules, microchips, drug implants, fast dissolving tablets, and multiphase release capsule types. Following the first medical operations of 3DP for the fabrication of custom prosthetics and dental implants, in the early 2000s, by computer grounded pre-design object the 3DP technology has been used to directly publish medical bias having largely complex 3D architectures, and fabricate medical bias to fit a case's own deconstruction.

3D printing technology first visible in 1884, when charles casing invents stereolithography he went on come theco- author of 3D system. in1980 there is major development dr.hideo kodama filled first patent for RP technology.in 1986 carl deckard constructed outfit for producing corridor by picky sintering.in 1989 patent was granted to carl deckard for SLA.in 1992 first SLA machine was produced using 3D system. in 1993, massachusetts institute of technology patented another technology, named 3Dimensional printing ways which is similar to the fit technology used in 2D printers.in 1993 3D printing patent was granted to E.M sachs. In1999 luke masella entered first 3D published bladder which was an amalgamation of 3D published biomaterial

and his own cell.in 2000 MCP technologies introduced the SLM technology. Development of finagled organs by 3D printing in 1999 brings new advances in medicine, as first lad- grown organ is implanted in humans.in 2001 first destok 3D printer was made by solid imension. 2002 was set up to be revolutionizing for medical field as first 3D published funtional order was finagled that is suitable to sludge blood and produce thinned urine in an animal.in 2004 dr.bowyer introduced the Rep- Rap generality of an open source, tone replicating 3D printer. in 2005 first colour 3D printer was introdused by z corp. in 2009 first 3D bio published blood vessels was produced by organovo. in 2011 3D printing was applied in gold and tableware world first 3D published bus, robotic aircraft was introduced. in 2015 there was great advancement in the pharmaceutical field as first 3Dprinted drug (spitram) manufactured by aprecia medicinal was approved by USFDA.

In early 2016, Spritam, a 3D published drug for onset seizures, came available in the United States. It's particularly useful for people who miss quotidian medicine pilules, performing in ineffective treatment results, due to its porous nature and design Spitam disintigrates in the mouth when taken with water, making it easier for normal cases to take. It's an cure to the difficulty of swallowing pills.aprecia submitted the new drug operation for drug to FDA december 2014. in march 2016 in us request the drug was launched.

TYPES OF 3D PRINTING

2.2.1) STEREOLITHOGRAPHY-:

Stereolithogaphy as the first 3D printing process, Charles Hull discovered it in 1988. Stereo lithography is the fashion in which a computer controlled ray ray is used to solidify the liquid polymer or resin, thereby creating a 3D structure. A ray or projector is used in stereo lithography to solidify material at the same time as it's solidified in a bulk terrain. The medicine will be answerable in a liquid tank of hydrogel or resin content using stereolithography, also known as print- polymerization. Photosensitive accoutrements are necessary. The substance incontinently solidifies when the ray light hits the face of the photosensitive, medicine- loaded material bed. It's a simple and effective system of producing largely accurate and instructional polymer pieces.Stereo lithography making the substance at a time one subcaste by ray ray which trace on the face of a handbasket of liquid photopolymer, which portable stage inside to support the part being to erected.

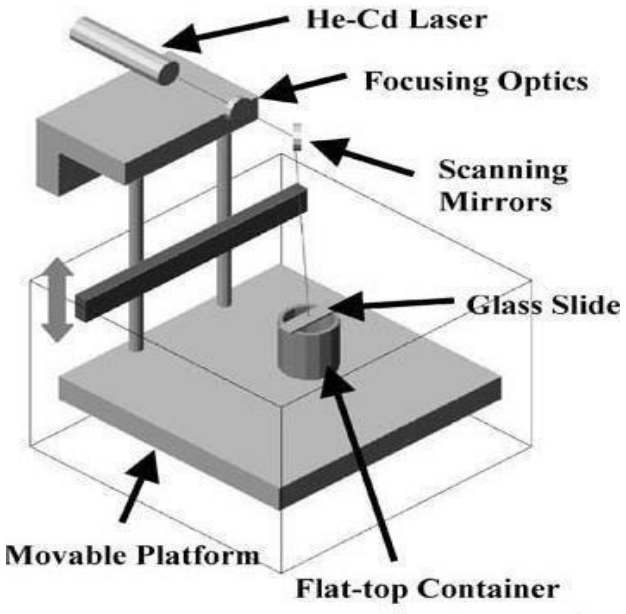

Fig 1 : Streolithography in 3D printing

Table no.1 Drug preapared from streolithography technique are:

Sr no.	Drug name	Dosage form	Use
1	Paracetamol	Oral modified release tablets	Antipyretic
2	4-Aminosalicylic Acid	Oral modified release tablets	Antibiotic
3	Salicylic acid	Anti-acne patch	Psoriasis

ADVANTAGES-:

a. High Precision and Resolution

- SLA uses a UV laser to cure resin layer by layer, allowing for **micron-level precision**.
- Ideal for creating **complex drug geometries**, controlled-release profiles, or personalized dosage forms.

b. Customization and Personalization

- Easily tailor drugs to **individual patient needs** (e.g., dosage, shape, release kinetics).
- Enables **on-demand** production of patient-specific medications.

c. Complex and Multi-Layered Structures

- Capable of fabricating **multi-compartment tablets** or **porous structures** for modified drug release.
- Useful for **polypharmacy** (multiple drugs in one tablet) and **targeted delivery systems**.

d. Rapid Prototyping and Production

- Allows for **fast design iterations**, reducing development time.
- Useful for **clinical trials** or experimental formulations with quicker turnaround.

e. Reduced Waste and Material Efficiency

- Additive process leads to **minimal material wastage**.
- Good for **expensive or sensitive pharmaceutical ingredients**.

f. Improved Drug Stability

- Controlled environment during printing (e.g., low heat) can protect **temperature- sensitive APIs**.
- Suitable for **bioactive compounds**, proteins, or peptides.

DISADVANTAGES-:

a. Limited Material Availability

- SLA primarily uses **photopolymer resins**, which may not be **biocompatible or pharmaceutically safe**.
- Fewer **FDA-approved materials** compared to other methods like FDM (Fused Deposition Modeling).

b. Post-Processing Requirements

- Requires **washing, curing, and removal of supports**, which can be time-consuming.
- Post-processing may affect the **uniformity or stability** of the drug.

c. Potential Toxicity of Resins

- Many SLA resins contain **toxic or irritant components**, making them unsuitable for **oral or injectable medications** unless specially formulated.
- Risk of **residual monomers** in the final product.

d. Slow Production Speed

- SLA is **slower** than other 3D printing methods, especially for high-volume production.

- More suited for **prototyping** or small batches than mass manufacturing.

e. Equipment and Maintenance Costs

- SLA printers are generally **more expensive** and require **more maintenance**.
- The need for **controlled environments** and specialized handling can increase operational costs.

f. Moisture and Light Sensitivity

- Printed components can be **sensitive to humidity and light**, requiring **careful storage**.
- May affect drug **stability and shelf life**.

2.2.2) THERMAL INK JET PRINTING-:

TIJ uses **tiny resistive heaters** to rapidly boil a small amount of liquid, forming a **vapor bubble** that ejects a precise droplet of formulation through a nozzle onto a substrate. In pharmaceutical applications, the "ink" is typically a **drug-loaded solution or suspension**.

Advantages-:

a) **High Precision & Control**
o Allows **accurate dosing** of small amounts of APIs—ideal for **personalized medicines**.

b) **Non-Contact and Digital**
o Enables clean, **on-demand production** with minimal contamination risk.

c) **Low Cost & Scalable**
o TIJ printers are **relatively inexpensive** and can be scaled for **industrial use**.

d) **Multimaterial Printing**
o Capable of printing **multiple APIs or excipients** by using separate cartridges.

e) **Room Temperature Operation**
o Suitable for **heat-sensitive compounds** (although the heating is localized and brief).

f) **Layer-by-Layer Drug Deposition**
o Supports creation of **complex drug release profiles**, including **immediate or sustained release**.

Disadvantages-:

a) **Formulation Limitations**
o Requires **low-viscosity fluids**, limiting the range of drug types and concentrations.

b) **Risk of Nozzle Clogging**
o Drug particles or crystallization can **block nozzles**, affecting print quality and dosage accuracy.

c) **Thermal Stress**
o Although brief, the **localized heating** can degrade **sensitive molecules**.

d) **Substrate Compatibility**
o Requires substrates that can **absorb or retain droplets**, which may limit design flexibility.

e) **Drop Placement Accuracy**
o Highly dependent on **printer calibration** and **environmental conditions** like humidity.

Applications-:

- **Personalized oral films** or **orodispersible tablets**
- **Microdosing** for pediatric or geriatric use
- **Rapid prototyping** of novel drug formulations

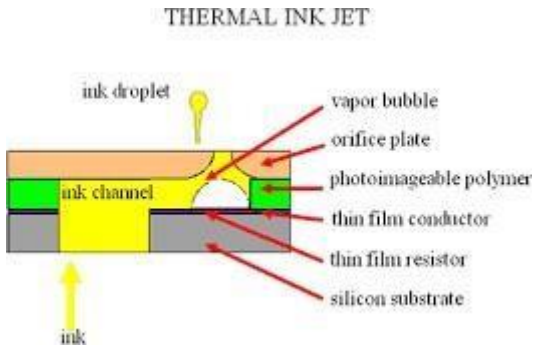

Fig 2: Thermal ink jet

Table no.2 Drug prepared from thermal ink jet 3D printing technique are :

Sr no.	Drug name	Dosage form	use
1	Folic acid	Nano suspension	Anemia
2	Felodipine	Solid dispersion	Antihypertensive
3	Prednisolone	Tablet	Anti-inflammatory
4	Terbutaline sulphate	Solution	Bronchodilator

2.2.3) INKJET PRINTING-:

Inkjet printing in **3D drug manufacturing** is a cutting-edge technique used to precisely deposit **active pharmaceutical ingredients (APIs)** and excipients, layer by layer, to create **customized medications**. It's part of the broader category of **additive manufacturing (AM)** and is especially useful for **personalized medicine**, **rapid prototyping**, and **on-demand drug delivery systems**.
Inkjet printing involves **jetting tiny droplets** of a drug formulation (usually a solution or suspension) onto a substrate.

Advantages of Inkjet Printing in Drug Manufacturing

a. Precision Dosing

- Allows **accurate microdosing** of APIs, down to **nanograms or micrograms**.
- Perfect for **pediatric**, **geriatric**, and **personalized dosing**.

b. Customization and Personalization

- Easily tailored to individual patients (e.g., **drug combination, dose, shape**).
- Enables **on-demand production** of specific medicines.

c. Gentle Processing

- Operates at or near **room temperature**, preserving **heat-sensitive drugs** (e.g., proteins, peptides).

d. Fast and Efficient

- Ideal for **rapid prototyping** and **high-throughput screening**.
- Minimal material waste—only uses what's needed.

e. Multi-Drug Capability

- Can print **multiple drugs simultaneously** with different nozzles.
- Supports **polypills** and **fixed-dose combinations**.

Disadvantages of Inkjet Printing in Drug Manufacturing

a. Formulation Constraints

- Requires **low-viscosity liquids**; high drug concentrations can clog nozzles.
- Solvent choice is limited due to **biocompatibility** and **volatility**.

b. Thermal Degradation Risk (in TIJ)

- Heat used in **thermal inkjet** may affect **drug stability**, though exposure is brief.

c. Limited to Thin Layers

- Not ideal for creating large, solid structures.
- Better suited for **films**, **coatings**, or **layered tablets**.

d. Maintenance and Clogging

- Nozzles can get **blocked** easily, affecting precision and consistency.

e. Scale-Up Challenges

- Transitioning from **lab-scale to industrial-scale** remains complex.

Common Applications

- **Orodispersible films**
- **Personalized tablets**
- **Drug-eluting implants or patches**
- **Rapid prototyping of drug formulations**

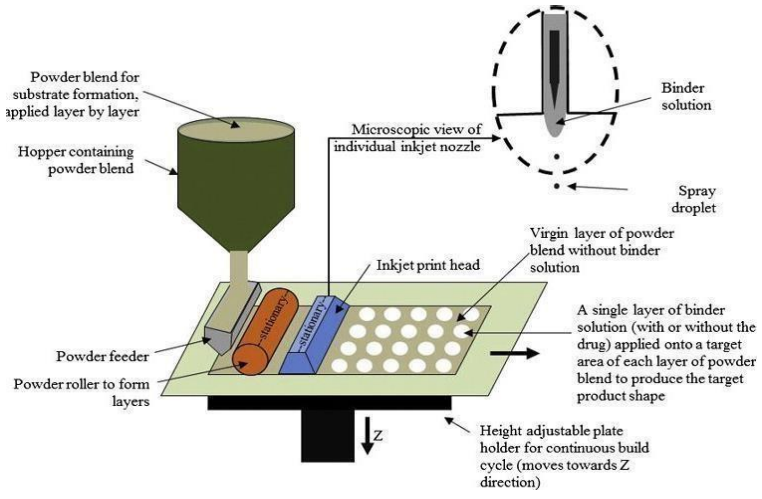

Fig 3: Ink jet printing

Table no.3 Drug prepared from ink jet printing technique are :

Sr no.	Drug	Dosage form	use
1.	Insulin	Microneedle	Antihyperglycemia
2.	Caffeine	Tablets or capsules	CNS stimulant
3.	Rifampicin	Rifampicin Implants , Nanoparticles	Antibiotic
4.	Folic Acid	Nanosuspension	Anemia
5.	Paracetamol	Tablets	Analgesics

2.2.4) Fused Deposition Modeling (FDM)-:

Fused Deposition Modeling (FDM) also called **Fused Filament Fabrication (FFF)**—is one of the most widely explored **3D printing techniques in drug manufacturing**. It's valued for its **simplicity, affordability, and versatility**, especially in creating **solid oral dosage forms** like tablets and capsules.

In FDM, a **drug-loaded filament** (usually a thermoplastic polymer mixed with an API) is heated just above its melting point and **extruded layer by layer** to build a 3D structure, such as a **tablet** or **implant**.

Advantages-:

a. **Low Cost & Accessibility**
   - FDM printers are **inexpensive**, widely available, and **easy to operate**.

b. **Custom Dosage & Shape**
   - Enables **personalized medicines** with specific doses, release profiles, or geometries.

c. **Controlled Drug Release**
   - By changing the **tablet shape, internal geometry**, or polymer type, you can modify **drug release kinetics** (immediate, sustained, or delayed release).

d. **Polypill Potential**
   - Can print **multiple APIs** in one tablet, ideal for patients taking several drugs.

e. **Good Mechanical Properties**
   - Produces tablets with **high mechanical strength** and **controlled porosity**.

Disadvantages-:

a. **High Temperature Limitations**
   - Requires **melting polymers**, which can degrade **heat-sensitive drugs** (e.g., proteins, peptides, vitamins).

b. **Limited API Compatibility**
   - Not all drugs can be **uniformly blended** with thermoplastic polymers.

- Some APIs may have poor **thermal stability or solubility** in the matrix.

c. Filament Preparation Required

- Often needs **hot-melt extrusion (HME)** to prepare drug-loaded filaments before printing.

d. Printer Modification May Be Needed

- Standard FDM printers may require **modifications** for pharmaceutical-grade work (e.g., temperature control, contamination prevention).

Applications of FDM in Pharma-:

- **Customized oral tablets** (e.g., heart-shaped, donut-shaped for controlled release)
- **Drug-loaded implants or patches**
- **Multi-layered polypills**
- **Pediatric or geriatric formulations**

Notable Example

Spritam® (levetiracetam) – the first **FDA-approved 3D printed drug**, used ZipDose® technology (similar in goal but different in method) to rapidly disintegrate in the mouth.

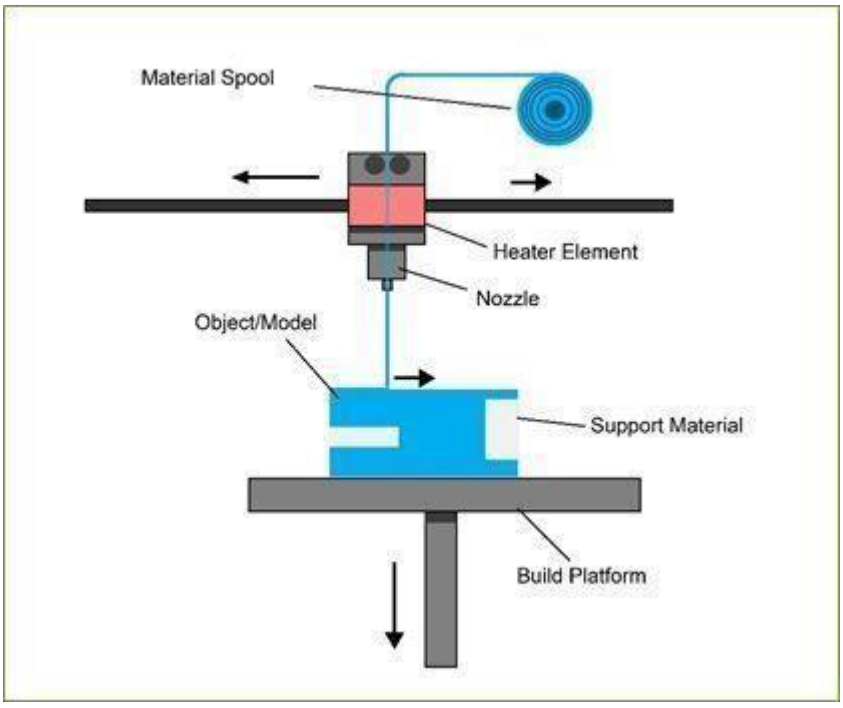

Fig 4: Fused deposition 3D printing

Table no.4 Drug preapared from Fused deposition 3D printing are :

Sr no.	Drug name	Dosage Form	Use
1	Ibuprofen	Tablet	NSAID
2	Metformin, Glimepiride	Tablet	Antidiabetic
3	Prednisolone	Extended release tablet	Immunosuppressant
4	Captopril	Intermediate release tablets	Hypertension,CHF
5	Enalapril maleate	Tablet	Antihypertensive

2.2.5) Selective Laser Sintering (SLS)-:

Selective Laser Sintering (SLS) is an advanced **3D printing technique** that is gaining attention in **drug manufacturing** due to its ability to produce **complex, porous, and customized dosage forms** without the need for binders or solvents.

SLS uses a **high-powered laser** to selectively fuse (or "sinter") fine **powder particles**— typically a polymer mixed with an active pharmaceutical ingredient (API)—layer by layer to build a 3D object.

Advantages -:

a. No Need for Binders or Support Materials

- The surrounding unsintered powder **supports the structure** as it's printed, eliminating the need for additional scaffolding or support.

b. Highly Porous Structures

- Can create **controlled porosity**, which is useful for **modifying drug release rates** or creating **fast-dissolving tablets**.

c. Precision and Complexity

- Ideal for producing **complex geometries** like hollow or compartmentalized dosage forms.

d. Single-Step Production

- Combines **formulation and shaping in one step**, simplifying the drug manufacturing process.

e. Solvent-Free

- No solvents involved, reducing concerns around **residual solvents** or **chemical degradation**.

Disadvantages-:

a. High Temperature

- Sintering requires **elevated temperatures**, which can **degrade heat-sensitive drugs**.

b. Limited Material Compatibility

- Only certain **thermally stable APIs and polymers** can be used.

c. Post-Processing Required

- The final product may need **removal of excess powder** and **sieving**, which can be time-consuming.

d. Cost and Complexity

- SLS printers are typically **more expensive** and complex than FDM or inkjet systems.

e. Regulatory Challenges

- Fewer **regulatory precedents** exist compared to other printing methods, which may slow clinical adoption.

Applications in Pharma-:

- **Porous tablets** for rapid or controlled drug release
- **Implantable drug delivery devices**
- **Personalized oral dosage forms**
- **Customized shapes** for pediatric or geriatric use

SLS holds **great potential** but is still mostly in the **research and development phase** for pharmaceuticals.

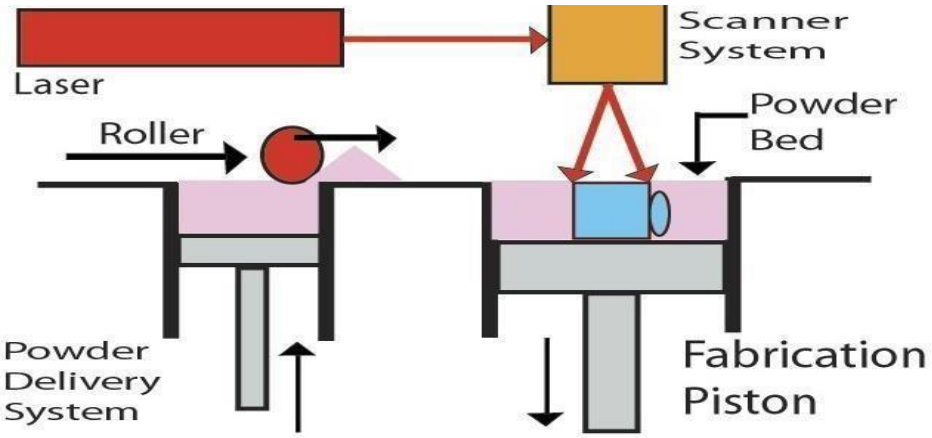

Fig 5 : Selective laser sintering

2.2.6) Extrusion-based 3D printing-:

Extrusion-based 3D printing is one of the most widely used techniques in pharmaceutical 3D printing. It works by pushing semi-solid, paste-like, or melted materials through a nozzle to form drug products layer by layer. This method includes Fused Deposition Modeling (FDM) and semi-solid extrusion (SSE), each suited for different types of formulations.
It involves extruding a material—either thermoplastic polymers (in FDM) or gel/paste formulations (in SSE)—onto a surface in a pre-programmed pattern. This allows for customizable shapes, dosages, and release profiles in drug manufacturing.

Advantages of Extrusion-Based Printing in Pharma-:

a. Personalized Medicine

- Enables patient-specific **dose, shape, size, and release profile** customization.

b. Multiple Drug Loading

- Can print **multi-drug formulations** (polypills) or **multi-layered tablets**.

c. Versatile Material Compatibility

- Works with a wide range of materials:

- FDM → **thermoplastic polymers** (e.g., PVA, PLA)
- SSE → **semi-solid pastes**, gels, or **hydrogels** (ideal for heat-sensitive APIs)

d. Controlled Release Profiles

- Tablet design (infill, geometry, layers) can control **immediate, sustained, or delayed release**.

e. Simple and Scalable

- Printers are **affordable**, and process can be **scaled** for small batch production or clinical use.

Disadvantages of Extrusion-Based Printing

a. Thermal Sensitivity (in FDM)

- High temperatures in FDM may **degrade sensitive APIs**.
- SSE avoids this but has other limitations.

b. Moisture Sensitivity (in SSE)

- Semi-solid formulations may **require drying** or **stabilization**, which adds extra steps.

c. Need for Preprocessing

- Often requires **filament extrusion** (for FDM) or **paste preparation** (for SSE) before printing.

d. Limited Resolution

- Lower precision compared to SLA or inkjet printing—can affect **dose accuracy** in some cases.

e. Formulation Challenges

- APIs must be **compatible** with the extrusion process and materials (e.g., miscibility, stability).

Applications

- **Custom tablets** for pediatrics, geriatrics, or rare diseases
- **Polypills** for polypharmacy
- **Buccal, sublingual, or transdermal patches**
- **Immediate or controlled release systems**

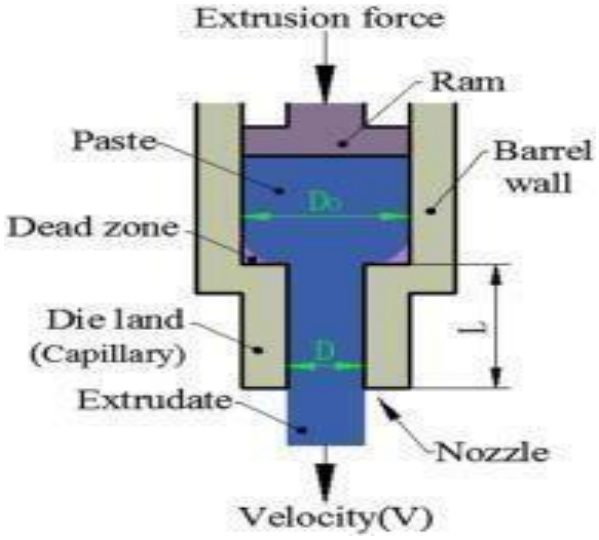

Fig 6 : Extrusion-based printing

Table no.5 Drug preapared from Extrusion-based 3D printing technique are :

Sr no	Drug name	Dosage form	Use
1	Captopril	Tablet	Anti-hypertensive
2	Glipizide	Tablet	Anti-diabetic
3	Nifedepine	Tablet	Anti-hypertensive
4	Prednisolone	Tablet	Immunosuppressive drug
5	Polydimethylsiloxane	Tablet	Surfactant

2.2.7) Hot Melt Extrusion (HME)-:

Hot Melt Extrusion (HME) is a critical pre-processing technique in 3D printing for drug manufacturing, especially in Fused Deposition Modeling (FDM). It involves melting and mixing a drug with a polymer to create a drug-loaded filament, which is then used for 3D printing customized dosage forms. HME is a solvent-free process where a blend of active pharmaceutical ingredients (APIs) and thermoplastic polymers is heated, mixed, and pushed through an extruder to form a homogeneous filament. This filament is later used in FDM-based 3D printing to create tablets or implants.

Advantages of HME in Drug 3D Printing

a. Uniform Drug Distribution

- Ensures even dispersion of the API throughout the polymer matrix, improving **dose uniformity**.

b. Solvent-Free

- Avoids the use of solvents, reducing concerns about **residual solvents** and improving **environmental safety**.

c. Enhances Drug Solubility

- Converts poorly soluble drugs into **amorphous solid dispersions (ASDs)**, improving **bioavailability**.

d. Compatible with FDM

- Produces **print-ready filaments** for FDM printers, enabling **custom dosage** and **drug release profiles**.

e. Continuous Manufacturing

- Can be integrated into a **continuous pharmaceutical production** line, improving scalability and efficiency.

Disadvantages of HME in Drug Manufacturing

a. High Processing Temperature

- Not suitable for **heat-sensitive APIs** (e.g., peptides, proteins) due to thermal degradation risks.

b. Polymer Selection is Limited

- Only works with **thermoplastic polymers** that melt without degrading (e.g., PVA, PLA, Eudragit).

c. Complex Equipment Setup

- Requires **specialized extruders** and strict **temperature, pressure, and screw speed control**.

d. Stability Issues

- Amorphous drugs produced via HME may have **long-term stability issues** without proper polymer selection.

Applications in 3D Drug Printing

- **Drug-loaded filaments** for FDM
- **Solid dispersions** to improve **bioavailability**
- **Personalized tablets** with tailored geometry and drug release
- **Combination therapies (polypills)**

Example:

- **HME + FDM** is the typical workflow to create **personalized, modified-release oral tablets** in 3D printing research.

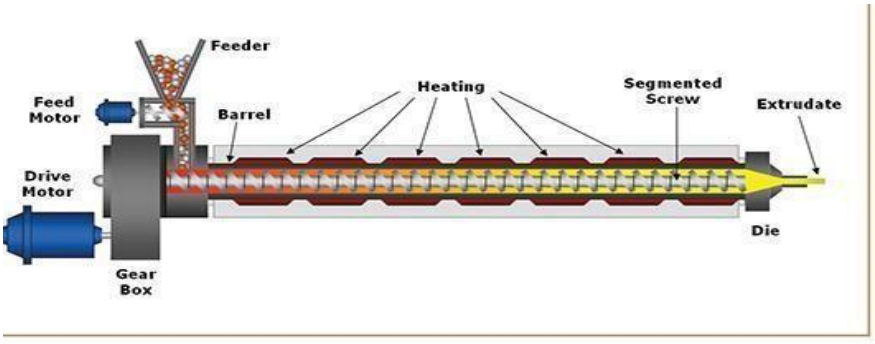

Fig 7 : Hot melt extrusion

Table no.6 Drug preapared from Hot melt extrusion 3D printing technique are :

Sr no	Drug name	Dosage form	Use
1	Paracetamol	3D-printed—cube	Analgesic

2	**Domperidone**	**Tablet**	**Parkinson's disease**
3	**Hydroxypropyl Cellulose**	**Tablet**	**Keratoconjunctivitis**
4	**Rifampicin**	**Compartmentalized shells**	**Antibiotic**
5	**Indomethacin**	**Subcutaneous rods**	**NSAIDS**

2.2.8) ZIPDOSE TECHNIQUE-:

The ZipDose® technology is a revolutionary 3D printing technique in drug manufacturing, best known for being used in Spritam® (levetiracetam)—the first FDA- approved 3D-printed drug (approved in 2015). It was developed by Aprecia Pharmaceuticals and is designed to produce rapidly disintegrating tablets with high drug loads.
ZipDose® uses a powder bed inkjet 3D printing process where a liquid binding agent is selectively deposited onto layers of powdered pharmaceutical ingredients. The binder solidifies the powder in the desired shape, and the process is repeated layer by layer until a full tablet is built.

ADVANTAGES-:

a. Ultra-Rapid Disintegration

- **Tablets dissolve within seconds in the mouth without water, ideal for patients with swallowing difficulties (e.g., elderly, pediatric, or neurological patients). b. High Drug Load**

- **Can incorporate up to 1,000 mg of API in a single rapidly disintegrating tablet— unmatched by traditional ODTs (orally disintegrating tablets).**

c. Precision and Consistency

- **Ensures accurate dosing with each print layer, suitable for individualized medicine.**

d. Complex Structures

- **Enables intricate internal designs that enhance tablet porosity and dissolution behavior.**

e. No Compression

- **Unlike conventional tablet pressing, ZipDose avoids compression, preserving the structure of fragile or sensitive APIs.**

DISADVANTAGES-:

a. Limited to Specific Formulations

- **Not all APIs or excipients are compatible with the powder-bed and binder system.**

b. High Production Cost

- **Equipment and formulation development can be expensive, limiting access for smaller-scale manufacturers.**

c. Moisture Sensitivity

- **The highly porous tablets can be sensitive to humidity, requiring special packaging.**

d. Proprietary Technology

- **Controlled by Aprecia Pharmaceuticals, which limits widespread use or replication by others without licensing.**

Applications-:

- **Epilepsy treatment (Spritam®)**
- **Potential expansion to high-dose ODTs for other CNS conditions, pain relief, or chronic diseases**
- **Suitable for patients with dysphagia or those requiring fast-onset medication**

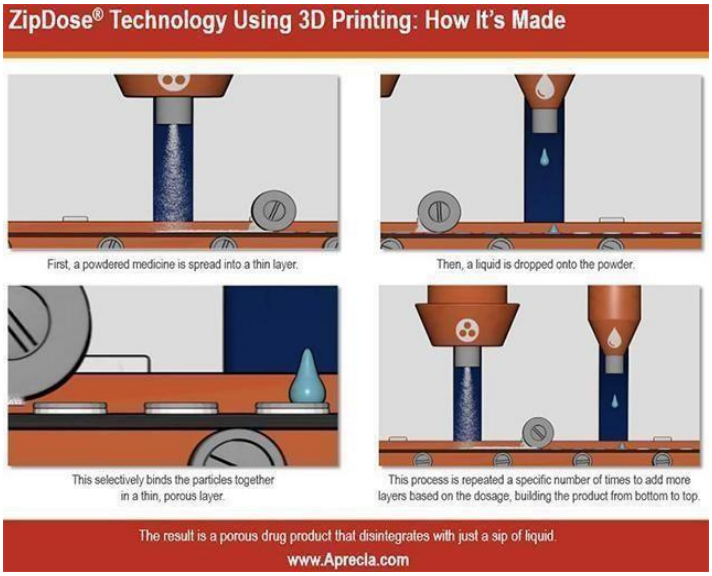

Fig 8: Zip dose

ADVANTAGE AND DISADVANTAGE OF 3D PRINTING DRUGS-:

Advantages of 3D Printing Drugs-:

a) **Personalized Medicine**
   - Doses, release profiles, and combinations of drugs can be tailored to individual patient needs.

b) **On-Demand Production**
   - Medications can be printed in hospitals or pharmacies as needed, reducing waste and storage issues.

c) **Complex Drug Designs**
   - Enables creation of complex geometries (e.g., multi-layer tablets, polypills) for controlled or timed release.

d) **Faster Prototyping and Development**
   - Drug prototypes can be quickly printed and tested, speeding up R&D timelines.

e) **Improved Patient Compliance**
   - Custom shapes, flavors, and drug combinations make medications more appealing and easier to take.

f) **Reduced Manufacturing Costs (Long-Term)**
   - Minimizes large-scale infrastructure and allows more flexible production models.

Disadvantages of 3D Printing Drugs-:

g) **Regulatory Challenges**

- FDA and other agencies need to develop clear guidelines; approval processes are still evolving.

h) **High Initial Costs**

o Equipment and setup costs are high, and skilled technicians are needed.

i) **Limited Material Options**

- Not all drug compounds and excipients are suitable for 3D printing technologies yet.

j) **Scalability Issues**

- Printing large quantities of medications is currently less efficient than traditional methods.

k) **Stability and Shelf Life Concerns**

- Some printed drugs may have uncertain stability over time compared to conventional tablets.

l) **Intellectual Property Risks**

- Easier to copy and reproduce drug designs could raise issues around counterfeit or unauthorized drugs.

MATERIALS AND Methods of 3D Printing in Drug Manufacturing-:

Materials Used in 3D Printing of Drugs-:

Material Type	Examples	Purpose
Active Pharmaceutical Ingredients (APIs)	**Paracetamol, Ibuprofen, Sildenafil, Levodopa**	**The actual drug providing therapeutic effect**
Polymers	**PVA (Polyvinyl alcohol), PLA (Polylactic acid), HPMC (Hydroxypropyl methylcellulose)**	**Used as binders, carriers, or release modifiers**

Plasticizers		
	Glycerol, Triethyl citrate	**Enhance flexibility and printability**
Fillers & Excipients		
	Lactose, Mannitol, MCC (Microcrystalline cellulose)	**Add bulk and improve processing**
Solvents		
	Water, Ethanol, Isopropanol	**Used in semi-solid extrusion or inkjet** printing

Material Type	**Examples**	**Purpose**
Colorants & Flavors	Approved dyes, sweeteners	Improve patient compliance and product appeal

Methods of 3D Printing in Drug Manufacturing-:

Method	**Description**	**Advantages**	**Common Uses**
Fused Deposition	Melts and extrudes thermoplastic for d-	Widely used, simple, good	tablets, sustained-

Modeling (FDM)	filaments layer-by-layer	heat-stable drugs	release forms

Method	**Description**	**Advantages**	**Common Uses**
Inkjet Printing (Drop-on-Powder)	Deposits high drug-containing liquid droplets onto powder layers	High precision, suitable for low-dose drugs	Fast-dissolving tablets
Stereolithography (SLA)	Uses light to cure a photopolymer resin layer-by-layer	Very precise smooth finish	Niche drug delivery systems
Laser (SLS)	Uses laser to sinter powdered material into complex	No binder needed for modified good materials	Polypills, **Selective Sintering**-released

Method	**Description**	**Advantages**	**Common Uses**

	tion	tages	Use s
Semi-solid Extrusion (SSE)	solid ex syst forms structu ems res Extrude s a paste or gel contain ing soft drug and excipie nts	Good for tempe rature-sensiti ve APIs	Bucc al film s, tabl ets
Binder Jetting	Sprays a binder heat red onto a neede or powder bed to custo bind particle e ase s dosage tabl togethe forms ets r	No d, yed- mizabl	Laye dela rele

RESULT AND DISCUSSION-:

3D printing has been used in drug for a long time, starting with the creation of dental implants. now it has expanded into the healthcare assiduity, where it's used to produce dental implants. It also provides the Organ printing to produce cells, biomaterials, and cell- laden accoutrements separatly by subcaste by subcaste and directly creating 3D towel like structure. It substantially targets on the two implicit spots to rise pharmaceutical product development to unexplored areas, manufacturing sophisticated structures for the delivery and substantiated drug.

- Towel AND ORGAN BIOPRINTING Organ printing uses this to subcaste cells, biomaterials, and cell- laden biomaterials to make 3D towel-suchlike structures.A heart stopcock, a spinal slice, colorful kinds of cartilage and bone, and an artificial observance have all been created using 3D printers.
- ANATOMICAL MODELS Neurosurgeons can profit from 3D- published neuro- anatomical models because they give a representation of some of the most complex structures in the mortal body.
- ZIP Lozenge By manufacturing extremely pervious material, it delivers a customised cure in addition to the delivery of a high medicine- cargo with high decomposition and dissolution situations.
- COMMERCIALLY AVAILABLE 3D published medicines Aprecia medicinals manufactured first FDA approved 3D published medicine which is Spritam by the help of ZipDose fashion grounded on greasepaint bed emulsion. Spritam made by the subcaste- by- subcaste product arrangement. Spritam's pharmacological effectiveness was set up to be similar to that of conventional tablets. Because of its pervious and answerable matrix composition, the solubilization time of Spritam has been drastically reduced.
- 3D PRINTING FOR CANCER TREATMENT-: Chemotherapy is generally used in cancer treatment, but it can have unintended consequences. Chemotherapeutic medicines have a low solubility in water, making them delicate to use therefore, they are administering through a different route. presently, the construction of patches loaded with- fluorouracil, poly (lactic- coglycolic) acid, and PCL have been efficaciously published and implanted directly into pancreatic cancer (35).

CONCULSION-:

3D printing has come a useful and implicit tool for the pharmaceutical sector, leading to individualized drug concentrated on the case's requirements. By their working principles, colorful 3DP approaches have been developed and divided into subgroups. Selective ray sintering, inkjet printing, and extrusion grounded printing, hot melt, streolithography, fused deposit, zip cure were presented as applicable 3D printing styles for medicine manufacturing. 3DP technology has increased the capability to cover the shape and microstructures of lozenge forms, allowing for the development of largely complex products and complex medicine lozenge forms. It may ameliorate its operations in Pharmaceutical Research and Biotechnological fields. In the fields of medicine delivery and medicinal/ medical device product, 3DP has a lot of pledge. The future of medicinals lies in 3D printing for medicine product.

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