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3D PRINTING IN PERSONALIZED MEDICINE: A REVIEW

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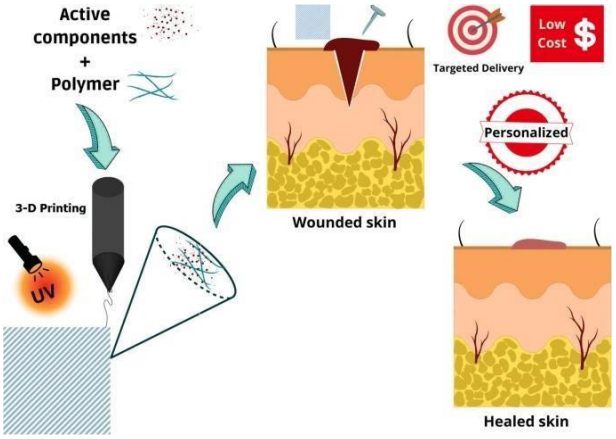
ABSTRACT

3D printing is a new technology that can make customized medicines for each person.Instead of giving everyone the same tablet or dose, doctors can use 3D printing to design drugs that match a person's genes, body needs, and disease type.It works by building medicines layer by layer using computer designs.Different 3D printing methods like Fused Deposition Modeling (FDM), Stereolithography (SLA), Inkjet printing, and others are used.In healthcare, 3D printing can:Make personalized tablets (polypills) combining many drugs in one pill.Create patient-specific implants, prosthetics, and surgical models. Help in cancer treatment by making accurate models for surgery or radiation.It has advantages like accuracy, customization, and fewer side effects,but also challenges such as high cost,regulation issues, and production setup problems.Overall, 3D printing is changing how medicines are made and given, moving healthcare towards personalized treatment for every patient.

KEYWORDS: 3D printing, biomedical applications, additive manufacturing, tissue engineering, bioprinting, medical devices.



INTRODUCTION:

Definition of 3D Printing (Additive Manufacturing):

3D printing, also known as Additive Manufacturing (AM), is a modern technology that creates three-dimensional objects layer by layer from a digital model.Instead of cutting or molding materials (as in traditional manufacturing), 3D printing adds materials successively, forming complex shapes and designs directly from a computer-aided design (CAD) file.In the healthcare field, 3D printing is used to produce:

- Customized medical devices (implants, prosthetics)
- Patient-specific drug dosage forms
- Surgical instruments
- Anatomical models for surgery planning[11]

Brief History and Evolution of 3D Printing in Healthcare

- **1980s:** The concept of 3D printing emerged, mainly for industrial use. The first commercial 3D printer was introduced by Charles Hull in 1986 using the Stereo lithography (SLA) technique.
- **1990s**: Biomedical applications began with printing of prosthetic parts and dental models.
- **2000s**: Introduction of bio printing, which involves printing living cells, tissues, and scaffolds for regenerative medicine.
- **2010s:** Present: Rapid development in printing of personalized drugs, implants, bone and organ models, and tailor-made dosage forms.
- **Today**: 3D printing is integrated with AI, genomics, and personalized medicine, creating individualized healthcare solutions.

Concept of Personalized Medicine

Personalized Medicine means designing medical treatments specifically for an individual patient based on their:

Genetic makeup -

- ✓ Age, weight, and metabolism
- ✓ Disease type and stage
- ✓ Response to specific drugs

Instead of a “one-size-fits-all” approach, personalized medicine focuses on giving the right drug at the right dose to the right person.

For example:

1. A diabetic patient may get a customized insulin release tablet 3D printed for their metabolism rate.
2. Cancer patients may get targeted drug delivery systems based on tumor biology.

Importance of Combining 3D Printing and Personalized Medicine

Combining these two technologies has several advantages:

1. Customized Dosage Forms:

Each patient can receive tablets or capsules specifically designed for their required dose, shape, or release pattern.

2. Improved Patient Compliance:

Personalized tablets (e.g., with controlled taste, size, or shape) make medication easier to take, especially for children and elderly patients.

3. Efficient Drug Delivery:

3D printing allows multi-drug combinations in a single pill
(polypills), controlling the release of each drug at different times.

4. Reduced Side Effects:

Since doses are optimized per individual, the risk of overdose or underdose is minimized.

5. Faster Prototyping and Production:

3D printers can rapidly design and produce new formulations without the need for large manufacturing setups.

6. Cost-Effective in the Long Run:

Personalized treatments reduce hospital visits and trial-and-error drug prescriptions.

7. Future Potential in Bioprinting:

3D bioprinting could create human tissues, bones, or even organs, which can be patient-specific for transplants

Principle:

3D printing of medicines, also called additive manufacturing, works on the principle of layer-by-layer fabrication of pharmaceutical products based on digital designs. The main ideas are:

1. **Digital Design-Based Manufacturing**

Medicines are designed using computer-aided design (CAD) software.

The structure, shape, and dose of the drug are digitally defined according to patient-specific needs.

2. **Layer-by-Layer Deposition**

The medicine is built one layer at a time, allowing precise control over .

- ✓ Dosage
- ✓ Drug release profiles (immediate or sustained)
- ✓ Shape and size (e.g., chewable, orodispersible, complex geometries)

3. **Personalization**

The principle enables patient-specific customization, considering:

- ✓ Age, weight, metabolism
- ✓ Genetic profile
- ✓ Disease type and severity

4. **Controlled Drug Release**

Different drugs or polymers can be printed in specific spatial arrangements, allowing:

- ✓ Multi-drug combinations in a single tablet
- ✓ Tailored release kinetics (fast, delayed, or sustained)

5. **Compatibility with Various Printing Technologies**

Methods such as Fused Deposition Modeling (FDM), Stereolithography (SLA), Inkjet Printing, or Semi-solid extrusion use this principle to produce:

- ✓ Tablets
- ✓ Implants
- ✓ Capsules
- ✓ Personalized dosage forms

Types of 3D Printing Techniques Used in Pharmaceuticals

1. **Inkjet Printing (Binder Jetting**)

Principle: A liquid binder or drug solution is precisely deposited onto a powder bed layer by layer.

Uses:

- ✓ Printing tablets and oral dosage forms.
- ✓ Producing porous structures that dissolve rapidly.

Example:

Spritam® (levetiracetam): The first FDA-approved 3D-printed tablet (by Aprecia

Pharmaceuticals).

2. Fused Deposition Modeling (FDM)

Principle: A thermoplastic polymer filament (mixed with drug) is melted and extruded layer by layer to build the object.

Uses:

- ✓ Personalized drug dosage forms.
- ✓ Sustained or controlled-release tablets.
- ✓ Multi-drug combinations in one print.

3. Stereolithography (SLA)

Principle: Uses ultraviolet (UV) laser light to solidify liquid photosensitive resin layer by layer.

Uses:

- ✓ Printing complex geometries and microstructures for drug delivery.
- ✓ Fabrication of microneedles and implants.

4. Selective Laser Sintering (SLS)

Principle: A laser beam sinters (fuses) powder particles (drug + polymer) layer by layer without melting them completely.

Uses:

- ✓ Oral dosage forms with controlled release.
- ✓ Printing of heat-stable drugs and solid dispersion

5. Pressure-Assisted Microsyringe (PAM) / Semi-Solid

Principle: A syringe-like printer head extrudes a semi-solid paste (drug + polymer) to form layers.

Uses:

- ✓ Printing gels, ointments, and transdermal patches.
- ✓ Suitable for thermolabile (heat-sensitive) drug.

6. Hot Melt Extrusion (HME)–Based Printing:

Principle: Drug and polymer are melted and mixed, then extruded through a nozzle to form

dosage units.

Uses:

✓ Sustained-release and taste-masked formulations.

7. **Inkjet-Based Bioprinting**:

Principle: Similar to inkjet printing, but uses bio-inks containing living cells and biomaterials.

Uses:

✓ Tissue engineering, wound healing, and personalized implants.

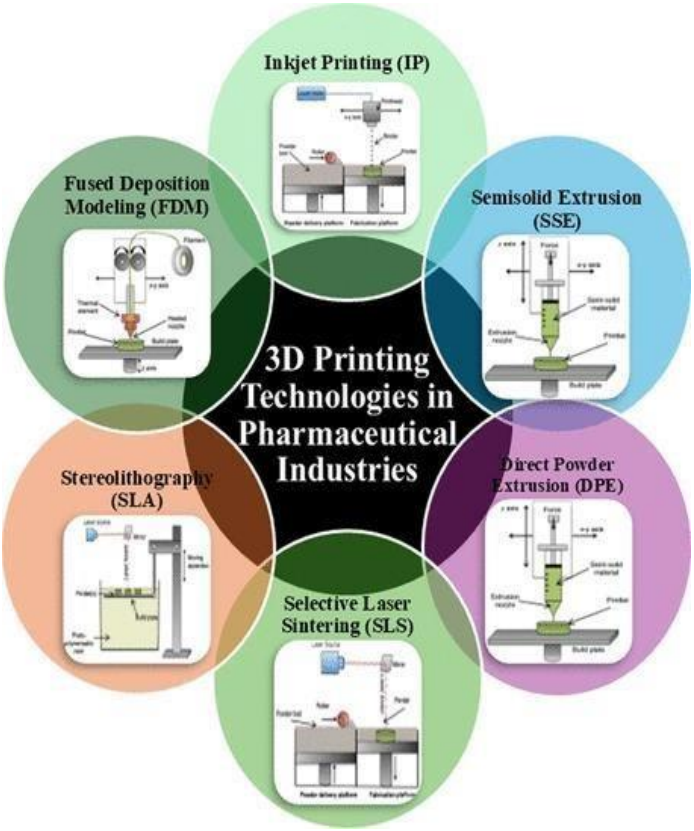


Fig 2. Schematic representation of commonly used 3D printing techniques in the pharmaceutical industry.

Materials Used for 3D Printing Technology in Manufacturing Industry:

1. **Metal:**

Metal 3D printing has gained a lot of attention in fields like

aerospace, automobiles, medicine, and manufacturing because of its many advantages. Metals have excellent physical properties and can be used to make very complex parts — from

human implants to aircraft components.

Common metals used in 3D printing include aluminium alloys, cobalt-based alloys, nickel-based alloys, stainless steel, and titanium alloys.

2. Polymers:

Polymers are used in 3D printing to make devices work better and provide mechanical support, especially in orthopedic implants.

3. Ceramics:

3D printing can now make ceramic objects without cracks or big holes by adjusting printing settings. Ceramics are strong, durable, and fire-resistant. They can take almost any shape, making them great for construction, buildings, dental, and aerospace uses.

Examples

✓ Alumina: Can be 3D printed into complex shapes with high `density and strength. Used in electronics, aerospace, chemicals, and more.

✓ Bioactive glass: 3D printing improves its strength, making it useful for bone scaffolds.

✓ Zirconia: Used in nuclear power because it resists radiation and heat.

4. Composites:

Composites are materials made by combining two or more materials to get better properties like strength, light weight, and durability.

Examples:

Carbon fiber-reinforced polymers: Strong, stiff, corrosion- resistant; used in aerospace.

Glass fiber-reinforced polymers: Cheap, strong, heat-resistant; widely used in 3D printing.

5. Smart Materials:

Smart materials can change shape or properties when exposed to things like heat, water, light, or electricity.

Examples**:**

Shape memory alloys (e.g., nickel-titanium): Used in medical implants and micro-devices.Shape memory polymers (SMPs): Can change shape with stimuli and are easy to 3D print.

6. Special Materials:

- Food: 3D printing can make food like chocolate, pizza, or spaghetti. You can adjust ingredients without losing taste or nutrients.
- Lunar dust: 3D printing could make multi-layered parts from moon dust for future space missions.
- Textiles: 3D printing can be used in jewelry and clothing, saving time and reducing cost.

Global 3D Printing Market Size and Pharmaceutical Industry:

3D printing is changing medicine by making drugs and treatments that can be customized for each patient. The global 3D printing market is growing fast, from 20.68 billion USD in 2023 to anexpected 117.78 billion USD by 2033.In cancer care, 3D printing helps make personalized implants, drug carriers, and surgical models, allowing better treatment for complex cases where standard methods may not work.

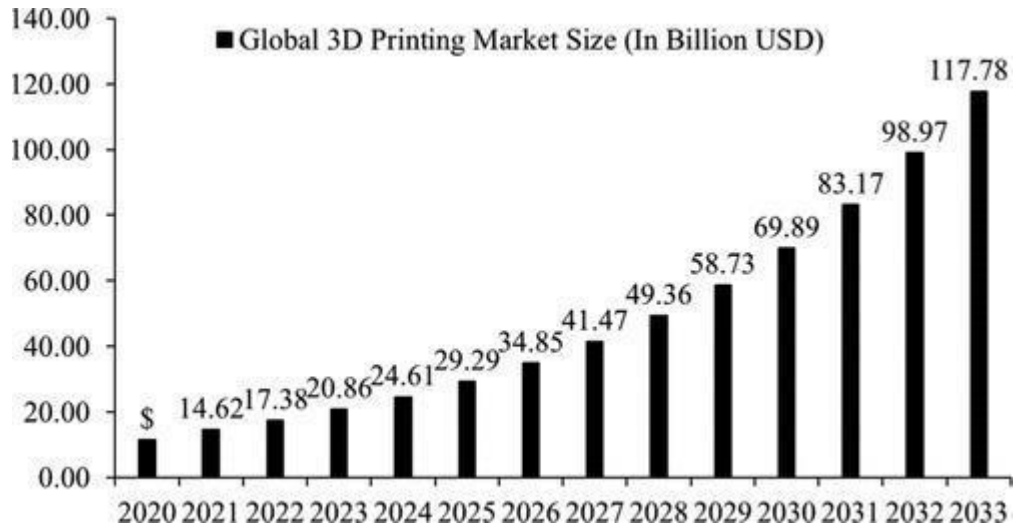


Fig 3: Illustration of the global 3D printing market size and trends from 2014 to 2025 in billions.

USD Problems and challenges in 3D printing:

3D printing is making rapid prototyping possible. It has a large number of advantages for manufacturing industries. But still, a lot of challenges and open issues are there in the field of 3D printing.

- Loss of data during the 3D printing process
- Long time needed in 3D printing and Error in 3D printing output
- Remote access and control
- Low utilization
- Less information about resource
- Distribution of digital model
- Time estimation of 3D printing process

CONCLUSION: The introductory chapter deals with the 3D printing methodology used to produce it. It also educates us about the procedure of quick prototyping of additives. Then we talk about the several principle approaches for 3D printers that comprise stereo lithography,

fused deposition modeling, selective laser melting and a lot more. Different applications include the medical, automotive and aerospace sectors. Then 3D printers examine the pros and downsides. Advances in 3D technology can revolutionize.

REFERENCES:

1. Englezos, K., Wang, L., Tan, E.C. and Kang, L., 2023. 3D printing for personalised medicines: implications for policy and practice. International journal of pharmaceutics, 635, p.122785.
2. Tan, G., Ioannou, N., Mathew, E., Tagalakis, A.D., Lamprou, D.A. and Yu-Wai-Man, C., 2022. 3D printing in Ophthalmology: From medical implants to personalised medicine. International Journal of Pharmaceutics, 625, p.122094.
3. Konta, A.A., García-Piña, M. and Serrano, D.R., 2017. Personalised 3D printed medicines: which techniques and polymers are more successful?. Bioengineering, 4(4), p.79.
4. Grof, Z. and Štěpánek, F., 2021. Artificial intelligence based design of 3D-printed tablets for personalised medicine. Computers & Chemical Engineering, 154, p.107492.
5. Rodríguez-Pombo, L., de Castro-López, M.J., Sánchez-Pintos, P., Giraldez-Montero, J.M., Januskaite, P., Duran-Piñeiro, G., Bóveda, M.D., Alvarez-Lorenzo, C., Basit, A.W., Goyanes, A. and Couce, M.L., 2024. Paediatric clinical study of 3D printed personalised medicines for rare metabolic disorders. International Journal of Pharmaceutics, 657, p.124140.
6. Denis, L., Jørgensen, A.K., Do, B., Vaz-Luis, I., Pistilli, B., Rieutord, A., Basit, A.W., Goyanes, A. and Annereau, M., 2024. Developing an innovative 3D printing platform for production of personalised medicines in a hospital for the OPERA clinical trial. International Journal of Pharmaceutics, 661, p.124306.
7. Krueger, L., Miles, J.A., Steadman, K.J., Kumeria, T., Freeman, C.R. and Popat, A., 2022. 3D printing: potential clinical applications for personalised solid dose medications. Medical Journal of Australia, 216(2).
8. Panova, N.K., Nikolova, K.T. and Dikova, T.D., 2025. Analysis of advanced technologies for 3D printing of pharmaceutical products for personalised medicine: A review. Archives of Materials Science & Engineering, 132(1).
9. Elbadawi, M., McCoubrey, L.E., Gavins, F.K., Ong, J.J., Goyanes, A., Gaisford, S. and Basit, A.W., 2021. Disrupting 3D printing of medicines with machine learning. Trends in pharmacological sciences, 42(9), pp.745-757.

10. Goyanes, A., Scarpa, M., Kamlow, M., Gaisford, S., Basit, A.W. and Orlu, M., 2017. Patient acceptability of 3D printed medicines. International journal of pharmaceutics, 530(1-2), pp.71-78.
11. Alzoubi, L., Aljabali, A.A. and Tambuwala, M.M., 2023. Empowering precision medicine: the impact of 3D printing on personalized therapeutic. Aaps Pharmscitech, 24(8), p.228.