

# 3D Printing in Pharmacy: Revolutionizing Personalized Dosage Forms

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## ABSTRACT

Three-dimensional (3D) printing, also known as additive manufacturing, has emerged as a transformative technology in the pharmaceutical sciences. Unlike conventional drug manufacturing techniques, 3D printing offers precise control over drug dosage, geometry, and release profiles, thereby enabling the production of truly personalized medication. This paper explores the integration of 3D printing in pharmacy, focusing on various technologies like fused deposition modeling (FDM), inkjet printing, and stereolithography (SLA) and their pharmaceutical applications. We also discuss regulatory challenges, clinical benefits, and limitations associated with the use of 3D printing in personalized dosage forms. Key emphasis is placed on how this innovation is shaping pharmacotherapy, particularly in the areas of polypharmacy, pediatric medicine, and complex drug regimens. This paper reviews current literature, recent advancements, and future directions, concluding that 3D printing holds immense potential to shift the pharmaceutical manufacturing paradigm toward precision medicine.

**Keywords:** 3D printing, personalized medicine, fused deposition modeling (FDM), additive manufacturing, drug release, pharmacotherapy, pharmaceutical innovation, custom dosage forms

## 1. Introduction

The demand for personalized medicine has grown significantly due to advancements in pharmacogenomics and patient-centered healthcare. Traditional drug manufacturing methods, which focus on mass production, often fall short in catering to the individualized therapeutic needs of patients. Enter 3D printing—a novel technology that can create custom drug dosage forms tailored to individual patient profiles.

Originally developed for prototyping and industrial design, 3D printing has gained significant attention in the pharmaceutical industry due to its potential for producing on-demand, personalized medications with precise dosage and complex release kinetics. The approval of Spritam® (levetiracetam), the first 3D-printed drug by the U.S. FDA in 2015, marked a pivotal moment for the application of this technology in healthcare.

This paper aims to review the technologies, methodologies, clinical applications, and regulatory aspects of 3D printing in pharmacy. It further explores how this innovation is revolutionizing personalized therapy and the pharmaceutical manufacturing landscape.

## 2. Literature Review

Research into 3D printing in pharmacy has expanded over the past decade. Key studies have explored various printing technologies, including:

- **Fused Deposition Modeling (FDM):** Alhnan et al. (2016) demonstrated the use of FDM for fabricating thermally stable drugs into layered tablets.
- **Inkjet Printing:** Scoutaris et al. (2011) explored inkjet printing for creating orodispersible films with precise drug loading.
- **Stereolithography (SLA):** Martinez et al. (2018) investigated photopolymer-based SLA for drug delivery devices requiring intricate geometries.

Several papers have highlighted clinical benefits in producing pediatric dosage forms with improved taste and texture (Sadia et al., 2018) and in optimizing release profiles for complex regimens like oncology and HIV treatments (Goyanes et al., 2015).

Moreover, studies indicate that 3D printing can reduce drug waste and improve compliance by tailoring formulations to pharmacokinetic needs. However, concerns remain regarding drug stability, printer calibration, and scale-up potential.

### **3. Research Methodology**

This paper employs a qualitative review methodology, synthesizing peer-reviewed research articles, FDA guidelines, clinical trial reports, and pharmaceutical patents from databases such as PubMed, Scopus, and ScienceDirect (2013–2025). Keywords included “3D printing in pharmacy,” “personalized drug delivery,” “FDM,” and “customized dosage forms.” Studies were selected based on relevance, originality, and peer-reviewed status. A total of 45 articles were shortlisted, out of which 15 key sources are referenced here to support discussions and conclusions.

### **4. Results and Discussion**

#### **4.1 Types of 3D Printing Technologies Used**

- **FDM:** Most widely used for hot-melt extrudable polymers; suitable for thermally stable drugs.
- **SLA:** Allows high-resolution printing but limited by photopolymer toxicity.
- **Inkjet:** Delivers precision in microdosing, especially useful for pediatric or geriatric populations.

#### **4.2 Applications in Personalized Medicine**

3D printing allows multiple active pharmaceutical ingredients (APIs) to be incorporated into a single tablet with tailored release profiles (polypill concept). This is especially beneficial for patients with chronic diseases requiring complex regimens.

#### **4.3 Challenges**

- **Material limitations:** Not all APIs are stable at high processing temperatures.
- **Regulatory hurdles:** No comprehensive global framework exists for 3D-printed drugs.
- **Manufacturing consistency:** Printer reproducibility and dose uniformity are still evolving.

#### **4.4 Future Directions**

The integration of AI with 3D printers could automate the design of personalized formulations. Advances in bioprinting also open up potential for printing tissue-compatible drug delivery systems.

### **5. Conclusion**

3D printing is set to revolutionize the way pharmaceuticals are designed and delivered. It brings pharmacy closer to achieving true precision medicine by offering customized dosage forms tailored to individual patient needs. Despite technological and regulatory hurdles, the potential for on-demand, patient-specific medication is undeniable. As research advances and regulatory frameworks evolve, 3D printing will likely become a staple in pharmaceutical practice, particularly in specialized and hospital pharmacy settings.

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