

Advances in 3D Printing Technology for Orodispersible Tablets Represent a New Direction in Personalized Drug Delivery

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Abstract: ODTs are solid dosage forms that break down or dissolve quickly in the mouth without water. Orodispersible tablets (ODTs) have changed how we administer drugs, especially for children, elderly patients, and those who have difficulty swallowing. The arrival of 3D printing has improved the possibilities for ODTs by allowing precise control over drug dosage, shape, and release profiles. This supports the idea of tailored therapy. The printed formulation meets patient goals by providing the right dose based on individual needs and drug release patterns. Recently, 3D printing has emerged in pharmaceutical development, offering a chance to move away from standardized medication dosing and toward more precise and personalized treatments. Many technologies have been developed in the pharmaceutical field, but few offer the same advantages as 3D printing. This review looks at the latest advancements in 3D printing techniques for creating ODTs. It emphasizes different printing methods, formulation strategies, excipient choices, and regulatory issues. The article also discusses the challenges and future paths for clinical use and commercial implementation.

Keywords: 3D Printing, Orodispersible Tablets, Personalized Medicine, Fused Deposition Modeling, Inkjet Printing, Additive Manufacturing, Drug Delivery.

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I. INTRODUCTION

Orodispersible tablets (OTD) are solid dosage forms that dissolve fastly in the mouth and they are designed to dissolve on the tongue and then swallowed with the help of saliva.⁽¹⁾ Orodispersible tablets (ODTs) have emerged as a significant innovation in pharmaceutical drug delivery systems due to their unique advantages, as well as significant impact in dysphagia or mental health conditions who may struggle with swallowing conventional tablets. As a result, ODTs greatly enhance patient compliance and adherence to treatment regimens⁽²⁾ One of the key benefits of ODTs is their potential for a rapid onset of action. Since the medication dissolves quickly and can begin absorption through the oral mucosa, it is particularly useful in conditions requiring immediate therapeutic effects, such as allergies, pain, and nausea. Additionally, their ease of administration makes them highly convenient for patients who are traveling or in emergency situations, where access to water may be

limited.⁽³⁾ ODTs may also enhance the bioavailability of certain drugs by partially bypassing first-pass metabolism, which can allow for lower dosages and reduced side effects. From a commercial perspective, they offer pharmaceutical companies an opportunity to extend product life cycles and stand out in a competitive market by developing user-friendly formulations. Moreover, ODTs are now available for a wide range of therapeutic areas including antipsychotics, obesity, hypertension, and cardiovascular medications. This versatility highlights their growing role in modern medicine. Overall, orodispersible tablets represent a patient-centric advancement in drug delivery, combining efficacy, convenience, and compliance into a single dosage form.⁽⁴⁾

II. 3D PRINTING TECHNIQUES FOR OTDS

➤ *Binder Jet Printing (BJP)*

Binder Jet Printing (BJP), or Inkjet or Drop-on-Powder printing, has been identified as a potential 3D printing method for the production of orodispersible tablets (ODTs). The process consists of layer-by-layer addition of a liquid binder on top of a bed of powder made up of active pharmaceutical ingredients (APIs) and excipients. Owing to its heat-free, solvent-based character, BJP is especially ideal for thermolabile pharmaceuticals and allows the preparation of highly porous forms that can lead to facile disintegration in the mouth.⁽⁵⁾

BJP provides major benefits including dose customization, geometrically complex design, and improved patient compliance particularly in the pediatric and geriatric patient populations. Nonetheless, there are issues with attaining sufficient mechanical strength, avoiding drug-binder incompatibilities, and ensuring stability.⁽⁶⁾

The method received regulatory endorsement with the approval of the first FDA-approved 3D- printed product, Spritam® (levetiracetam), showcasing its clinical promise. Current studies are aimed at formulation optimization, binder choice, and post-processing techniques to enhance the reproducibility and scalability of BJP towards more pharmaceutical uses.⁽⁷⁾

➤ *Selective Laser Sintering (SLS)*

Sintering powders with a laser yields robust, porous tablets with customizable release profiles. SLS has been used to print ODTs that disintegrate in under 15 s and release less than 90 % of the drug within 5min.⁽⁸⁾

SLS is an powder bed fusion technology which utilizes laser energy to selectively heat powder particles, resulting in partial powder melting followed by the fusion of particles and subsequent solidification give 3D structure. SLS is a very popular techniques that consists of sintering thin layers of powdered materials which spread over the platform of a printing bed using a laser as power source.⁽⁹⁾

➤ *Fused Deposition Modeling (FDM)*

Fused Deposition Modeling (FDM) is one of the most common and accessible 3D printing technologies in use today. It works by extruding melted thermoplastic filament through a heated nozzle, building objects layer by layer based on a digital model. Popular materials include PLA, ABS, PETG, and TPU, each offering different properties for various applications.⁽¹⁰⁾

FDM is widely favored for its affordability, ease of use, and versatility in prototyping, educational tools, and even low-volume production of functional parts. However, it has limitations such as lower resolution, visible layer lines, and potential warping with certain materials. Despite this, its wide adoption across industries highlights its value as a reliable and cost-effective additive manufacturing method.⁽¹¹⁾

➤ *Stereolithography (SLA)*

Stereolithography (SLA) is an additive manufacturing process that utilizes a UV laser to selectively cure liquid photopolymer resin into solid layers to create highly accurate and detailed 3D parts. One of the first 3D printing processes, SLA is known for its high resolution, smooth surface finish, and capability to manufacture complex geometries with fine features.⁽¹²⁾

The process of SLA entails lowering a build platform into resin soup, where a laser burns out each layer according to a digital model. As each layer hardens, the platform moves down incrementally, with the part building up layer by layer. Parts printed with SLA usually need post-processing, such as rinsing and UV curing. SLA is common in applications requiring high precision and surface finish, including dental and medical models and intricate engineering prototypes. Though superior to FDM in accuracy, SLA printing is not without limitations, such as greater material expense, restricted mechanical strength of parts, and vulnerability to environmental conditions.⁽¹³⁾

➤ *Direct Powder Extrusion (DPE)*

Direct Powder Extrusion (DPE) is an emerging additive manufacturing technique that allows for the direct processing of powdered materials—typically thermoplastics or composites— without the need for filament production. Unlike traditional FDM, where a pre-formed filament is extruded, DPE involves feeding dry powder into a heated screw-based extruder, where it is melted and deposited layer by layer to form 3D parts.⁽¹⁴⁾

This process enables greater material flexibility and cost reduction by eliminating the filament- making step. It is particularly advantageous for processing high-performance polymers, customized material blends, and composites with functional fillers.⁽¹⁵⁾

DPE is gaining interest in industrial applications due to its potential for producing large, structurally robust parts and supporting material innovation. However, challenges remain in ensuring consistent flow, precise temperature control, and uniform layer deposition, which are critical for print quality and mechanical performance. As the technology matures, Direct Powder Extrusion is expected to expand the capabilities of additive manufacturing by offering more sustainable, scalable, and material-diverse solution.⁽¹⁶⁾

➤ *Innovative Applications & Benefits in ODT Design*

Additive manufacturing (AM) technologies—Fused Deposition Modeling (FDM), Stereolithography (SLA), and Direct Powder Extrusion (DPE) particularly—have been creating new pathways in Orally Disintegrating Tablets (ODTs) development. These technologies enable fine control of tablet geometry, porosity, and drug distribution, which are the key parameters determining disintegration time and drug release behavior.

Customization of ODTs to specific patient requirements facilitates the development of personalized medicine, particularly for pediatric, geriatric, and dysphagic patients. AM also facilitates the production of multi-drug tablets, intricate inner architecture, and quick-dissolving porous architecture, all of which can be designed for a particular therapeutic response.

From a production viewpoint, AM conserves material waste, reduces development time, and provides on-demand manufacturing within clinical or offshore locations. These advantages not only enhance efficiency but also provide more flexibility in meeting patient-specific needs. Overall, the incorporation of additive manufacturing in ODT design is a big leap towards patient-centered pharmaceutical care, providing novel, scalable, and affordable.⁽¹⁸⁻¹⁹⁾

➤ *Volumetric Printing for Rapid Fabrication*

A new volumetric 3D-printing approach enables whole tablets to be cured in a single pass rather than layer by layer. This allows fabrication of pills in mere seconds, with adjustable release profiles based on resin formulation and geometry. Researchers believe this method has transformative potential for scalable personalized drug manufacturing, including complex “polypills”.⁽²⁰⁻²¹⁾

➤ *Hybrid SLS–FDM for Targeted Release*

An innovative study combined SLS-printed cores with FDM-printed coatings to achieve intestine-targeted release. The FDM layer boosts handling strength and fine-tunes disintegration and release, while hot-melt extrusion avoids solvent use—advantageous for environmental and regulatory compliance.⁽²²⁾

III. FDM 3D PRINTING & EXCIPIENTS FOR ENHANCED PERFORMANCE

➤ *High Drug Loading*

For instance, FDM was used to create orodispersible tablets loaded with up to 70% fluconazole, achieving stable formulations that disintegrated within 3 minutes and released over 95% of drug in 30 minutes even after long-term storage.

➤ *Dissolution Control via Fill Density*

FDM allows dissolution tuning by manipulating infill density. Higher density yields slower release and vice versa.

They are also collaborating with BioNTech to explore oral RNA delivery using multi-layer 3D-printed designs.⁽²³⁾

IV. BROADER IMPLICATIONS FOR PERSONALIZED MEDICINE

➤ *Dose and Geometry Modulation:*

3D printing especially via CAD/CAM - enables precise customization of tablet shape, infill, and architecture to fine-tune delivery profiles or combine APIs.

➤ *Tailored for Specific Populations:*

Especially beneficial for children and elderly, 3D-printed ODTs and films can overcome swallowing difficulties while allowing individualized dosing.

➤ *Polypills & Multifunctionality:*

MM-IJ3DP and MED technologies expand the possibility of integrated, multi-drug release in single dosage forms designed per patient needs.⁽²⁴⁻²⁵⁾

Summary Table 1 : New Developments in 3D Printing for ODTs

Technique	Advantage
MM-IJ3DP	Spatial control of release via soluble/insoluble architecture
Volumetric Printing	Ultra-fast pill production
FDM Hybrid	Targeted GI release with robust handling
FDM (High API Load)	Up to 70% drug loading with fast disintegration release
Fill Density Tuning (FDM)	Controlled dissolution across various APIs

V. CONCLUSION

3D printing technologies introduce a paradigm change in the manufacture of personalized ODTs, overcoming patient-specific characteristics such as fast disintegration, flexible dosing, taste masking, and accessible design. Although challenges exist in the form of material safety, thermal constraints, and regulatory acceptance the opportunities for these technologies to revolutionize individualized therapy are enormous. Through design flexibility, controlled-release kinetics, and patient-centric innovations, 3D-printed ODTs are opening up a new avenue for personalized medicine.

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