AN OVERVIEW ON ADVANCES IN ORAL-FAST DISSOLVING FILM TECHNOLOGY: FORMULATION STRATEGIES AND FUTURE PERSPECTIVES

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ABSTRACT

Oral dissolving films are a way to give people medicine that is easy to take. These oral dissolving films are very thin. They break down quickly in the mouth without needing any water. This means the medicine from the dissolving films gets into the body fast. They are easy for people to take. Oral dissolving films are especially good for kids and older adults who have trouble swallowing pills. Oral dissolving films can also help the body absorb the medicine from the dissolving films better. They do this by letting the medicine enter the body before it reaches the stomach. This way, the medicine from the dissolving films is not broken down much by the liver. This article discusses how oral dissolving films are made and what is important for them to work well. It also talks about the materials that can be used to make dissolving films and how to make oral dissolving films taste good. There are ways to make oral dissolving films, including using special machines that can print them. The article also discusses how to ensure oral dissolving films are high quality and how to test them. It is important to make dissolving films in a way that is safe and effective. Oral dissolving films are a way to give people medicine. They may be used more in the future to make medicine that is just right for each person. Overall, oral dissolving films are an idea. They can help people get the medicine they need in a way that is easy to take.

Keywords: Oro-dispersible films, buccal drug delivery, taste masking, hot-melt extrusion, quality by design, patient compliance.

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1. INTRODUCTION

The oral route is still the most common way to deliver drugs in modern medicine because it is non-invasive, easy to use, and most patients prefer it. Still, many people have trouble swallowing traditional solid pills. This problem, known as dysphagia, often happens because of age-related declines in muscle coordination and less saliva, especially in older adults and children who may not have the coordination needed to swallow tablets safely. Studies show that up to 26% of people have swallowing disorders, and these issues are even more common in institutional care settings (2). These difficulties can lead to patients not taking their medicine, skipping doses, or crushing or splitting tablets incorrectly, which can change how the drug works or even expose caregivers to harmful substances. Oral fast-dissolving films (OFDFs) offer a practical and patient-friendly answer to this problem. These thin, flexible strips are made from a water-loving polymer that swells quickly when placed on the tongue, releasing the medicine in seconds without needing water (3). This technology started as a consumer product for freshening breath and has now become a sophisticated pharmaceutical dosage form (4). OFDFs also help the drug absorb through the mouth lining, which can reduce the amount broken down by the liver, increase how much of the drug gets into the body, and help the medicine start working faster (5).

Oral dissolving films, or OFDFs, have many advantages, but they are still hard to make work properly. This is because they have some problems: they are not strong, the dose is not uniform, they do not taste good, they get damaged by moisture, and it is hard to make a lot of them. So, we need to understand how to design OFDF formulations, what is important for OFDF quality, how to make OFDFs, and what rules apply if we want OFDFs to be sold successfully. This review covers how to make dissolving films, what polymers to use for fast-dissolving films, how to manufacture them, how to test them, what can go wrong, what the rules say, and what is new with oral fast-dissolving films. We focus on designing fast-dissolving films well from the start so we can make oral fast-dissolving films

that patients like. We also consider future opportunities in medicine and smart oral fast-dissolving films that deliver drugs, which is a big deal for oral fast-dissolving films.

2. RATIONALE AND CLINICAL NEED FOR ORAL FAST-DISSOLVING FILMS

2.1 Addressing Dysphagia and Improving Compliance

Older adults are increasing in number across the world, and there is increased polypharmacy and age-related dysphagia. Other common problems in older people are xerostomia, oesophageal dysmotility, and weakness of the neuromuscular system, which make tablets difficult to swallow (6). Many people crush the tablets without clinical advice, which has the potential to cause 'dose dumping' in modified-release tablets. The water-free administration approach of OFDFs allows for maintaining the physiological limits and therapeutic integrity. There are analogous issues that exist in the paediatric population. Solid dosage forms are difficult to swallow by young children, and liquid dosage forms are difficult to swallow, may not be palatable, and may fail to be stable or may be dosed inaccurately (7).

A rapidly dissolving film that sticks to the tongue without applying pressure will reduce expulsion opportunities and may include child-friendly flavours, improving treatment acceptability and compliance (8). Patients with psychiatric or neurodegenerative diseases can benefit from OFDFs. Films that stick to the oral mucosa are not easily removed or hidden, which is a great advantage in supervised administration for patients with schizophrenia or Parkinson's (9).

2.2 Enhanced Bioavailability and Rapid Onset

The oral mucosa is well vascularized, with direct systemic access that avoids gastrointestinal degradation and hepatic metabolism. Certain drugs that are extensively metabolised, such as opioids, anti-emetics and cardiovascular drugs, show an improvement in bioavailability when administered through OFDF (10). This is confirmed by commercial products such as Suboxone® (buprenorphine/naloxone) film, in which the effect of sublingual absorption is essential for the management of opioid dependence (11). Rapid disintegration also exposes the drug in the pre-solubilised form directly to the stomach, which would be absorbed more quickly than compact tablets that need to disintegrate in the stomach (12).

3. DESIGN PRINCIPLES AND CRITICAL QUALITY ATTRIBUTES

Successful formulation of oral fast-dissolving films (OFDFs) requires a balance between mechanical strength, rapid disintegration, drug release, and patient acceptability. These properties are considered critical quality attributes (CQAs) because they directly influence the safety, efficacy, and stability of the formulation.

3.1 Mechanical Properties

Mechanical properties are important in checking that OFDFs can withstand handling, packaging, and administration without breaking while allowing for rapid disintegration in the oral cavity (13). The important metrics are tensile strength, elongation at break, Young's modulus, and folding endurance.

1. **Tensile Strength:** It measures the maximum stress the film can withstand before breaking. Poor tensile strength can result in tearing during handling or packaging (14).
2. **Elongation at Break:** Elongation at break indicates film flexibility. Brittle films crack easily, but highly elastic films may fold during packaging.
3. **Young's Modulus:** Young's Modulus represents film stiffness. Lower values indicate softer, more flexible films.
4. **Folding Endurance:** Determines the number of folds a film can withstand without breaking. The polymer composition, the concentration of plasticiser, and the amount of moisture define it. Plasticisers such as glycerol and propylene glycol improve flexibility, but excessive amounts can cause tackiness (15).

3.2 Disintegration Behaviour

Rapid disintegration is an essential characteristic of OFDFs as it allows rapid drug release and start of action. Oro-dispersible films should disintegrate within 180 seconds, according to the European Pharmacopoeia, though formulations with disintegration times of less than 30 seconds are often favoured for improved patient acceptance (16). Disintegration occurs by rapid saliva penetration, polymer swelling, and matrix relaxation. Super-disintegrants such as croscarmellose sodium, crospovidone, and sodium starch glycolate enhance disintegration by stimulating water uptake and swelling (17). However, excessive concentrations may affect film transparency and mechanical strength.

3.3 Content Uniformity and Crystallinity

Uniform drug distribution is critical in OFDFs because these films often contain low drug doses across a small area. Poor content uniformity may lead to dose variation and inconsistent therapeutic results. Water-soluble drugs are usually uniformly dissolved in the polymer matrix, whereas poorly soluble drugs disperse as suspensions and require stabilisation during casting (18). Drugs can remain amorphous or recrystallise upon drying, depending on the formulation and storage conditions.

Amorphous drugs exhibit greater solubility and dissolution rates, but they may recrystallise under humidity or temperature stress, affecting stability and drug release. X-ray diffraction (XRD) and differential scanning calorimetry (DSC) are standard techniques to assess crystallinity and solid-state stability.

3.4 Organoleptic Properties

Organoleptic properties have a significant effect on patient compliance, especially in juvenile and geriatric populations. OFDFs dissolve quickly in the oral cavity, bringing the medication into close contact with taste receptors and requiring taste masking (19).

An ideal OFDF should have a pleasant taste, a smooth mouthfeel, quick hydration, and low grittiness (Fig 1). To improve patient acceptability and therapeutic adherence, the right sweeteners, flavours, and taste-masking methods should be carefully chosen.

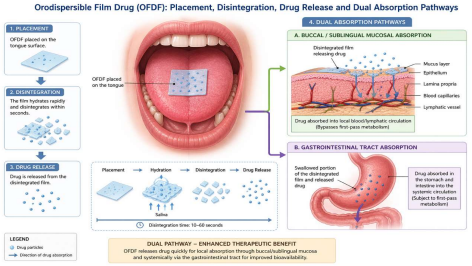

Figure 1 : Schematic diagram showing the OFDF anatomy and absorption pathway schematic

4. POLYMER-EXCIPIENT LANDSCAPE IN ORAL FAST DISSOLVING FILMS

The selection of suitable film-forming polymers and excipients plays a crucial role in determining the mechanical strength, disintegration behaviour, drug release, and patient acceptability of oral fast-dissolving films (OFDFs). An ideal polymer should possess good film-forming ability, rapid hydration, non-toxicity, and compatibility with the active pharmaceutical ingredient (API).

4.1 Conventional Film-Forming Polymers

Hydroxypropyl methylcellulose (HPMC) is one of the most widely used polymers in OFDF formulations because of its excellent film-forming ability, water solubility, and compatibility with various drugs (20). Low-viscosity grades such as HPMC E5 and E15 provide good mechanical strength while maintaining rapid disintegration.

Pullulan, a natural polysaccharide produced by *Aureobasidium pullulans*, forms transparent and rapidly dissolving films with excellent mechanical properties and low oxygen permeability. (21). Polyvinyl alcohol (PVA) is another commonly used hydrophilic polymer known for producing strong and flexible films with good adhesive properties (22).

Polyvinyl pyrrolidone (PVP) acts as both a film-forming agent and solubiliser. However, films prepared solely with PVP are often brittle and hygroscopic; therefore, it is commonly combined with polymers such as HPMC or sodium alginate to improve film stability and flexibility (23).

4.2 Innovative and Advanced Polymers

Recent research focuses on advanced polymers capable of improving mucoadhesion, controlled drug release, and patient compliance. Polyethene oxide (PEO) exhibits excellent mucoadhesive properties and enhances buccal retention by forming hydrogel-like films upon hydration (24).

Gellan gum, a natural anionic polysaccharide, forms strong films with improved mechanical stability and controlled disintegration behaviour, making it suitable for OFDF applications (25). Chitosan, a cationic biopolymer derived from chitin, provides mucoadhesive and permeation-enhancing properties that prolong drug residence time in the oral cavity (26).

Eudragit® polymers, particularly Eudragit E PO, are widely investigated for taste-masking applications because they remain insoluble in saliva but dissolve under acidic gastric conditions, thereby reducing bitterness perception (27).

4.3 Auxiliary Excipients

Auxiliary excipients are incorporated to optimise film performance and patient acceptability.

- **Plasticisers:** Glycerol and sorbitol improve film flexibility by reducing polymer brittleness, although excessive concentrations may cause tackiness (28).
- **Superdisintegrants:** Agents such as croscarmellose sodium and crospovidone promote rapid film disintegration and faster drug release.
- **Saliva-Stimulating Agents:** Organic acids such as citric acid and malic acid stimulate saliva secretion, improving hydration and disintegration of the film (29).
- **Sweeteners and Flavours:** Sweeteners such as sucralose, mannitol, and xylitol are commonly used along with flavouring agents to improve taste masking and patient acceptability (30).

5. TASTE MASKING STRATEGIES FOR ORAL FILMS

Taste masking is one of the most important formulation challenges in oral fast-dissolving films (OFDFs) because the drug is released directly in the oral cavity and comes into immediate contact with taste receptors. Therefore, effective taste masking is essential to improve patient acceptability and

compliance, particularly in paediatric and geriatric populations.

5.1 Flavour and Sweetener Systems

Flavours and sweeteners are commonly used as the first approach to reduce bitterness and improve palatability. Flavours such as mint, citrus, and berry help mask unpleasant taste sensations, while sweeteners including sucralose, aspartame, mannitol, and xylitol enhance mouthfeel and overall patient acceptability. However, flavouring agents alone may be insufficient for highly bitter drugs (31).

5.2 Ion Exchange Resin Complexation

Ion exchange resins (IERs) are insoluble polymers containing charged functional groups capable of binding oppositely charged drug molecules. In the oral cavity, the drug-resin complex prevents interaction between the drug and taste receptors, thereby reducing bitterness. In the acidic gastric environment, the drug is released through ion exchange mechanisms for subsequent absorption (32). This approach is highly effective but limited to ionizable drugs.

5.3 Cyclodextrin Complexation

Cyclodextrins (CDs) are cyclic oligosaccharides with hydrophobic cavities capable of forming inclusion complexes with drug molecules. Encapsulation of bitter drugs within the cyclodextrin cavity minimises drug interaction with taste receptors and improves taste masking efficiency (33). Hydroxypropyl-β-cyclodextrin is commonly preferred because of its high aqueous solubility and safety profile. In addition to taste masking, cyclodextrins can improve drug solubility and stability (34).

5.4 Physical Barrier Methods: Microparticle Coating

Physical barrier approaches prevent direct drug contact with taste receptors by coating or embedding the drug within protective matrices.

- **Microparticle Coating**: Bitter drug particles are coated with polymers such as Eudragit E PO, which remain insoluble in saliva but dissolve under gastric conditions, thereby minimising bitterness perception
- **Solid Dispersions by Hot-Melt Extrusion:** In this method, the drug is molecularly dispersed within polymer carriers, improving taste masking, dissolution behaviour, and bioavailability (35).

Overall, the selection of an appropriate taste-masking strategy depends on the physicochemical properties of the drug, formulation requirements, and desired patient acceptability (Fig 2).

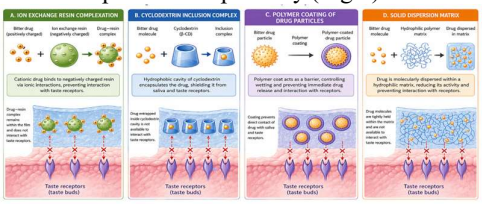

Figure 2: Comparative diagram of taste-masking mechanisms in OFDFs: (A) Ion exchange resin complexation, (B) Cyclodextrin inclusion complex, (C) Polymer coating of drug particles, (D) Solid dispersion matrix. Create a visual showing drug molecules being shielded

6. MANUFACTURING TECHNOLOGIES FOR ORAL FAST-DISSOLVING FILMS

Various manufacturing techniques have been developed for the preparation of oral fast-dissolving films (OFDFs), depending on the physicochemical properties of the drug, polymer characteristics, and desired film performance. The selected manufacturing method significantly influences film thickness, mechanical strength, drug uniformity, and disintegration behaviour.

6.1 Solvent Casting Method

Solvent casting is the most widely used technique for OFDF preparation due to its simplicity and ability to produce uniform films. In this method, film-forming polymers are dissolved in suitable solvents along with the drug and other excipients to form a homogeneous casting solution. The solution is then cast onto a flat surface, dried, peeled, and cut into individual films (36).

This method offers good content uniformity and is particularly suitable for heat-sensitive drugs. However, solvent removal requires controlled drying conditions, and the use of organic solvents may lead to residual solvent concerns and increased processing costs (37).

6.2 Hot Melt Extrusion (HME)

Hot-melt extrusion is a continuous and solvent-free manufacturing process gaining increasing importance in pharmaceutical applications. In this technique, the drug, polymer, and excipients are mixed and processed through a heated extruder containing rotating screws. The molten mass is then

extruded through a flat die to produce thin films (38).

HME eliminates the need for solvent evaporation and can improve drug solubility by forming amorphous solid dispersions. Additionally, it supports continuous manufacturing and enhanced taste masking. However, the process requires specialised equipment and may not be suitable for thermolabile drugs or polymers.

6.3 Semisolid Casting

Semisolid casting involves preparing a viscous gel or semisolid mass using polymers such as gelatine or pectin, followed by casting and controlled drying. This technique requires lower solvent volumes and is particularly useful for thermosensitive drugs and natural bioactive compounds (39).

6.4 Advanced Manufacturing Techniques

Recent advancements in additive manufacturing have expanded the potential of OFDF technology for personalised medicine and customised drug delivery systems (40).

- **Inkjet-Printing:**
  Inkjet printing deposits precise amounts of drug solution onto edible film substrates, allowing accurate dose customisation and multidrug incorporation (41).
- **Fused Deposition Modelling (FDM):**
  FDM is a three-dimensional (3D) printing technique in which drug-loaded polymer filaments are melted and deposited layer by layer to fabricate films with controlled geometry and drug release characteristics (42).
- **Extrusion-Based 3D Printing:**

This method involves extrusion of drug-containing gels through fine nozzles at room temperature, making it suitable for heat-sensitive drugs and multilayered formulations (43). Overall, the selection of an appropriate manufacturing method depends on drug stability, formulation requirements, scalability, and desired film properties (Fig 3).

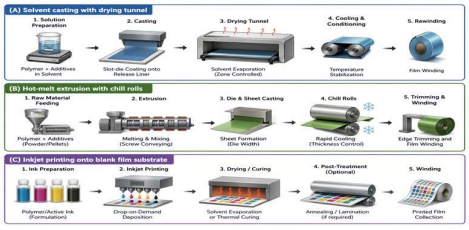

Figure 3 : Process flow diagram comparing manufacturing technologies: (A) Solvent casting with drying tunnel, (B) Hot-melt extrusion with chill rolls, (C) Inkjet printing onto blank film substrate. Include key process parameters for each method.

7. CHARACTERIZATION AND QUALITY CONTROL TESTS

Comprehensive characterisation and quality control testing are essential to ensure that oral fast-dissolving films (OFDFs) consistently meet the required critical quality attributes (CQAs) related to safety, efficacy, mechanical integrity, and patient acceptability. These evaluations are generally adapted from pharmacopoeia standards and specialised analytical methods developed for thin polymeric oral films (44). The major characterisation parameters, analytical instruments, and their pharmaceutical significance are summarised below in Table 1.

Table 1: Characterisation parameters and quality control tests for oral fast-dissolving films (OFDFs).

TEST PARAMETER	INSTRUMENT	SIGNIFICANCE
Thickness	Digital Micrometer	Influences dose uniformity and disintegration performance
Weight Variation	Analytical Balance	Indicates formulation uniformity and process reproducibility
Tensile Strength/Elongation	Texture Analyzer	Evaluates mechanical strength during handling and packaging
Folding Endurance	Manual/Automated Tester	Assesses flexibility and brittleness characteristics
Disintegration Time	Petri Dish/Slide Frame Assembly	Determines rapid film disintegration performance (<60 s)
Surface pH	pH Meter with Flat Electrode	Prevents irritation to oral mucosal tissues (pH 6.0–7.0)
Moisture Content	Karl Fischer Titration/Loss on Drying	Important for stability and prevention of

		recrystallisation
Drug Content Uniformity	HPLC/UV Spectroscopy	Confirms uniform API distribution within acceptable limits
In Vitro Dissolution	USP Apparatus (Paddle over Disk)	Evaluates drug release profile in simulated media
X-Ray Diffraction	Powder X-ray Diffractometer	Determines crystalline or amorphous nature of API
Scanning Electron Microscopy	Electron Microscope	Examines surface morphology and particulate distribution

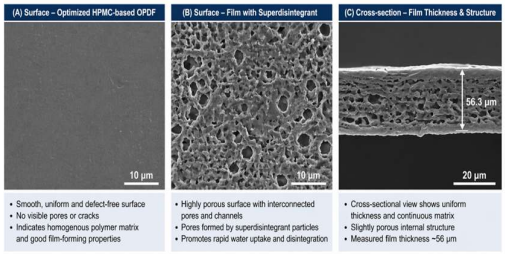

Figure 4: SEM Images of Oro dispersible Films Showing Surface and Cross-Sectional Morphology.

The slide frame assembly method is commonly employed to evaluate the disintegration behaviour of OFDFs by fixing the film within a frame and applying simulated salivary fluid while measuring rupture or disintegration time (45). In addition, morphological analysis using scanning electron microscopy (SEM) provides valuable information regarding surface
smoothness, pore formation, and homogeneity of drug distribution, all of which significantly influence film hydration, dissolution, and drug release characteristics (46) as shown in fig 4.

8. STABILITY CONSIDERATIONS AND PACKAGING REQUIREMENTS

Stability and packaging play a significant role in maintaining the quality, efficacy, and shelf life of oral fast-dissolving films (OFDFs). Due to the presence of hydrophilic polymers and their thin structural architecture, OFDFs are highly susceptible to environmental factors such as humidity, temperature fluctuations, and light exposure (47). Therefore, suitable packaging systems and controlled storage conditions are essential to preserve film integrity, mechanical properties, and therapeutic performance throughout the product life cycle.

8.1 Chemical and Physical Stability Challenges

Elevated moisture uptake can significantly alter the physical characteristics of OFDFs by reducing the glass transition temperature (Tg) of the polymeric matrix. When the Tg decreases below the storage temperature, the film may transition from a rigid glassy structure to a softer rubbery state, resulting in drug migration, stickiness, and possible recrystallisation of the active pharmaceutical ingredient (48). Furthermore, the high surface area-to-volume ratio of OFDFs increases the exposure of APIs to oxygen and environmental stress, thereby enhancing the possibility of oxidation and chemical degradation.

8.2 Packaging Solutions

Packaging materials for OFDFs should provide effective protection against moisture, oxygen, and light exposure while maintaining convenience during handling and administration.

• **Single-Unit Pouches:** Individual film packaging using multilayer laminated pouches composed of polyethene, aluminium foil, and polyester provides excellent moisture and light barrier properties. This packaging format effectively minimises environmental exposure and improves product stability, although it may increase packaging cost and material usage.

• **Multi-Unit Blister Packs:** High-barrier blister systems prepared using materials such as Aclar® or cyclic olefin copolymer are widely employed for OFDF packaging. Incorporation of desiccants further reduces residual moisture and enhances stability during storage. These systems improve patient convenience and facilitate dose organisation (49).

• **Roll Dispensers:** Roll-type dispensers are mainly suitable for relatively stable consumer products such as breath strips. However, their protective capability is generally insufficient for pharmaceutical OFDFs containing highly moisture-sensitive active ingredients.

Overall, appropriate packaging selection is essential to maintain the physicochemical stability, mechanical integrity, and therapeutic effectiveness of OFDF formulations during transportation and long-term storage.

9. REGULATORY AND QUALITY BY DESIGN PERSPECTIVES

OFDF development is guided by regulatory expectations and Quality by Design (QbD)

principles outlined in ICH guidelines (ICH Q8, Q9, Q10).

9.1 Regulatory Classification

In the United States, OFDFs are generally considered novel oral dosage forms. They may require submission through the 505(b)(2) New Drug Application pathway or Abbreviated New Drug Application (ANDA) pathway when an appropriate reference listed product is available (50). Although the United States Food and Drug Administration (FDA) has issued guidance related to orally disintegrating tablets, no separate regulatory guideline currently exists specifically for oral films. Nevertheless, regulatory considerations regarding disintegration testing, dissolution behaviour, bioavailability, and bioequivalence apply to OFDF formulations.

Generic OFDF products generally require comparative pharmacokinetic studies in human volunteers to establish bioequivalence with the reference product because in vitro dissolution testing alone may not adequately predict in vivo performance (51). Regulatory authorities also emphasise evaluation of content uniformity, stability, mechanical strength, packaging integrity, and patient acceptability during product development and commercialisation.

9.2 Application of Quality by Design

Quality by Design (QbD) provides a science-based and risk-oriented framework for the systematic development and optimisation of OFDF formulations (52).

1. **Quality Target Product Profile (QTPP):** A predefined summary describing the desired quality characteristics of the final dosage form, including rapid disintegration, acceptable taste, adequate mechanical strength, and long-term stability.
2. **Critical Quality Attributes (CQAs):** Physical, chemical, mechanical, and microbiological properties that must remain within predefined limits to ensure product quality, safety, and efficacy.
3. **Critical Material Attributes (CMAs) and Critical Process Parameters (CPPs):** Identification of formulation variables such as polymer viscosity, plasticiser concentration, and API particle size, along with processing conditions including drying temperature and casting speed, that may influence CQAs.
4. **Design Space:** Statistical tools and Design of Experiments (DoE) approaches are employed to establish relationships between CMAs, CPPs, and CQAs. The resulting multidimensional design space defines the operational ranges capable of consistently producing films with acceptable quality attributes.
5. **Control Strategy:** Comprehensive control measures involving raw material testing, in-process monitoring, and final product evaluation are implemented to ensure manufacturing consistency and product reliability (Fig 5).

Application of QbD principles is particularly important in OFDF development because film performance is strongly influenced by interactions among polymer composition, plasticiser concentration, drying conditions, and environmental factors during manufacturing and storage (53).

Figure 5: Ishikawa (fishbone) diagram illustrating factors affecting OFDF critical quality attributes. Include branches for Materials, Process, casting speed, Environment, and Equipment

10. BIOPHARMACEUTICAL CONSIDERATIONS AND IVIVC

The oral mucosal membrane provides a highly vascularized and permeable surface for drug absorption. Drugs administered through buccal or sublingual delivery pathways can directly enter the systemic circulation while partially bypassing gastrointestinal degradation and hepatic first-pass metabolism (54). This route is particularly advantageous for drugs that are acid labile or undergo extensive hepatic metabolism, thereby improving bioavailability and reducing variability in therapeutic response.

Establishing in vitro–in vivo correlation (IVIVC) for oral fast-dissolving films (OFDFs) remains a considerable challenge because drug absorption may occur through both oral mucosal and gastrointestinal pathways simultaneously (55). In addition, physiological variations in saliva composition, salivary flow rate, oral residence time, and swallowing behaviour can significantly influence drug dissolution and absorption characteristics.

Conventional dissolution methods may not accurately simulate the oral cavity environment; therefore, development of physiologically relevant dissolution models using small-volume media and controlled hydrodynamic conditions has gained increasing importance. Gittings and co-workers characterised human saliva as a potential biorelevant dissolution medium for evaluating oral film formulations and improving prediction of in vivo performance (56). Such approaches may contribute toward better IVIVC establishment and optimisation of OFDF formulations during pharmaceutical development.

11. CLINICAL APPLICATIONS AND COMMERCIAL PRODUCTS

The growing commercial success of oral fast-dissolving films (OFDFs) demonstrates their therapeutic potential across multiple clinical applications and patient populations (57).

These commercially available products highlight the versatility of OFDF technology in therapeutic areas including addiction management, neurology, pain management, and supportive care medicine (58) as showed in table 2 . Rapid disintegration, ease of administration, improved patient compliance, and the possibility of enhanced bioavailability contribute significantly to their clinical acceptance.

In addition, the availability of pre-formulated oral film platforms such as OrPhyllo™ has simplified extemporaneous compounding and individualised dose preparation in pharmacy settings. Such systems may reduce dosing errors while supporting personalised medicine approaches for paediatric, geriatric, and special patient populations requiring flexible dosage adjustments (59).

Table 2: Commercially available oral fast-dissolving film products and their therapeutic applications.

PRODUCT	API	INDICATION	MANUFACTURER
Suboxone®	Buprenorphine/Naloxone	Opioid dependence	Indivior
Zuplenz®	Ondansetron	Chemotherapy-induced nausea	Midatech
Kynmobi®	Apomorphine	Parkinson's OFF episodes	Sunovion
Belbuca®	Buprenorphine	Chronic pain	BioDelivery Sciences

12. CHALLENGES, GAPS, AND FUTURE DIRECTIONS

12.1 Persistent Challenges

- **High-dose drug incorporation:** because of the limited thickness and mass capacity of oral fast-dissolving films, drugs larger than 30-40 mg cannot be included, which may have adverse effects on mechanical properties, disintegration behaviour, and patient acceptance.
- **Mucoadhesive formulations:** Although a prolonged residence time may promote drug absorption, excessive mucosal adhesion may lead to discomfort and irritation during delivery.
- **Large-scale manufacturing:** To ensure reproducibility and product uniformity, multilayered and functionally complex OFDFs need to be produced using sophisticated technology and stringent process control.
- **Taste masking limitations:** Because no universal technique can be applied to all bitter active medicinal components, effective taste masking remains formulation-specific.
- **IVIVC establishment:** The development of credible in vitro-in vivo correlation models remains problematic due to the dual absorption pathways that involve both oral mucosal and gastrointestinal drug uptake.

12.2 Emerging Opportunities

- Personalised Medicine: Advanced printing technologies, such as inkjet printing, allow for the creation of individualised doses based on patient-specific therapeutic requirements. This method is particularly useful for pediatric patients and

medications with limited therapeutic indices (60).

- **Stimuli-Responsive Polymers**: Smart polymers that may respond to salivary pH, temperature, or enzymatic activity may enable site-specific and regulated medication release in the oral cavity (61).
- **Nanocarrier Incorporation:** Including nanoparticles, liposomes, nano-emulsions, and other nanocarrier systems in OFDFs can improve drug solubility, permeability, and targeted delivery, especially for poorly soluble and biological medicines (62).
- **Digital Health Integration:** The incorporation of ingestible sensors and digital monitoring technology into oral film systems may aid in medication adherence tracking and the creation of sophisticated digital treatments.
- **Continuous Manufacturing:** Emerging technologies such as hot-melt extrusion and continuous coating systems align with modern pharmaceutical manufacturing approaches focused on improving product quality, scalability, and cost-effectiveness (Fig 6).

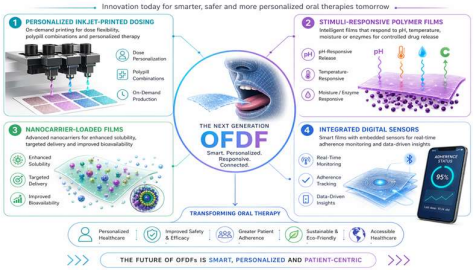

Figure 6: Future perspectives illustration

DISCUSSION

Oral dissolving films are a way to give people medicine. These Oral dissolving films are really good for kids, older adults and people who have trouble swallowing. When we look at what other people have written about dissolving films, we see that they work really well when we use the right materials to make them. We need to choose materials like the kind of plastic we use to make the film and the way we make it so that it is strong and dissolves quickly in the mouth. Some materials, like HPMC, pullulan and PVA, are really good at making films. We can also use materials to make Oral fast-dissolving films that work even better and give people the right amount of medicine. There are ways to make fast-dissolving films, like using a special liquid to make the film or using heat to melt the materials together. We can even use a kind of printer to make the films, which is really good for making medicine that is just right for one person. There are still some problems with fast-dissolving films, like how they can only hold a small amount of medicine and how they can be affected by moisture. Also, some people may not like the taste. It can be hard to make a lot of them at the time. We need to figure out how to make dissolving films that work the same way every time so that we can be sure they are safe and effective. If we can do this, then Oral dissolving films could be really great for giving people medicine in the future- medicine that is just right for one person and for using tiny particles to deliver medicine. Oral dissolving films are a promising way to give people medicine, and they could be used to make medicine that is tailored to each person's needs.

13. CONCLUSION

Oral fast-dissolving films (OFDFs) have emerged as an advanced and patient-focused drug delivery platform capable of improving treatment compliance and administration convenience, notably among paediatric, geriatric, and dysphagic patients. These methods combine rapid dissolution, ease of administration, and the potential for increased bioavailability via paragastric absorption pathways. Conventional polymers like HPMC and pullulan, as well as highly advanced mucoadhesive and stimuli-responsive polymers, have significantly improved film performance and patient acceptability.

Recent developments in manufacturing technologies, such as hot-melt extrusion and three-dimensional printing, have broadened the application of OFDFs to customised medicine and controlled drug delivery. Despite these advantages, challenges with dose loading, large-scale manufacturing, taste masking, stability, and the establishment of credible IVIVC models continue to impede wider adoption.

Nevertheless, continuous improvements in polymer science, nanotechnology, sophisticated manufacturing, and Quality by Design (QbD) procedures are expected to overcome these limitations in the near future. Commercially accessible OFDF medicines have previously demonstrated clinical efficacy in areas such as pain management, neurology, addiction treatment, and supportive care. Overall, OFDFs are a promising and emerging pharmaceutical dosage form with significant implications for future patient-centred drug delivery systems.

.**References**

1. Stegemann S, Gosch M, Breitkreutz J. Swallowing dysfunction and dysphagia are an unrecognised challenge for oral drug therapy. Int J Pharm. 2012 Jul;430(1–

2):197–206. doi:10.1016/j.ijpharm.2012.04.022
2. Schiele JT, Quinzler R, Klimm HD, Pruszydlo MG, Haefeli WE. Difficulties swallowing solid oral dosage forms in a general practice population: prevalence, causes, and relationship to dosage forms. Eur J Clin Pharmacol. 2013 Apr 29;69(4):937–48. doi:10.1007/s00228-012-1417-0
3. Dixit RP, Puthli SP. Oral strip technology: Overview and future potential. Journal of Controlled Release. 2009 Oct;139(2):94–107. doi:10.1016/j.jconrel.2009.06.014
4. Hoffmann EM, Breitenbach A, Breitkreutz J. Advances in orodispersible films for drug delivery. Expert Opin Drug Deliv. 2011 Mar 2;8(3):299–316. doi:10.1517/17425247.2011.553217
5. Bala R, Khanna S, Pawar P, Arora S. Orally dissolving strips: A new approach to oral drug delivery system. Int J Pharm Investig. 2013;3(2):67. doi:10.4103/2230-973X.114897
6. Lau ETL, Steadman KJ, Cichero JAY, Nissen LM. Dosage form modification and oral drug delivery in older people. Adv Drug Deliv Rev. 2018 Oct;135:75–84. doi:10.1016/j.addr.2018.04.012
7. Slavkova M, Breitkreutz J. Orodispersible drug formulations for children and elderly. European Journal of Pharmaceutical Sciences. 2015 Jul;75:2–9. doi:10.1016/j.ejps.2015.02.015
8. Zajicek A, Fossler MJ, Barrett JS, Worthington JH, Ternik R, Charkoftaki G, et al. A Report from the Pediatric Formulations Task Force: Perspectives on the State of Child-Friendly Oral Dosage Forms. AAPS J. 2013 Oct 2;15(4):1072–81. doi:10.1208/s12248-013-9511-5
9. Scarpa M, Stegemann S, Hsiao WK, Pichler H, Gaisford S, Bresciani M, et al. Orodispersible films: Towards drug delivery in special populations. Int J Pharm. 2017 May;523(1):327–35. doi:10.1016/j.ijpharm.2017.03.018
10. Lam JKW, Xu Y, Worsley A, Wong ICK. Oral transmucosal drug delivery for pediatric use. Adv Drug Deliv Rev. 2014 Jun;73:50–62. doi:10.1016/j.addr.2013.08.011
11. Reiner V, Giarratana N, Monti NC, Breitenbach A, Klaffenbach P. Rapidfilm®: An innovative pharmaceutical form designed to improve patient compliance. Int J Pharm. 2010 Jun;393(1–2):55–60. doi:10.1016/j.ijpharm.2010.03.055
12. Preis M, Woertz C, Schneider K, Kukawka J, Broscheit J, Roewer N, et al. Design and evaluation of bilayered buccal film preparations for local administration of lidocaine hydrochloride. European Journal of Pharmaceutics and Biopharmaceutics. 2014 Apr;86(3):552–61. doi:10.1016/j.ejpb.2013.12.019
13. Borges AF, Silva C, Coelho JFJ, Simões S. Oral films: Current status and future perspectives. Journal of Controlled Release. 2015 May;206:1–19. doi:10.1016/j.jconrel.2015.03.006
14. Morales JO, McConville JT. Manufacture and characterisation of mucoadhesive buccal films. European Journal of Pharmaceutics and Biopharmaceutics. 2011 Feb;77(2):187–99. doi:10.1016/j.ejpb.2010.11.023
15. Visser JC, Dohmen WMC, Hinrichs WLJ, Breitkreutz J, Frijlink HW, Woerdenbag HJ. Quality by design approach for optimizing the formulation and physical properties of extemporaneously prepared orodispersible films. Int J Pharm. 2015 May;485(1–2):70–6. doi:10.1016/j.ijpharm.2015.03.005
16. Preis M, Gronkowsky D, Grytzan D, Breitkreutz J. Comparative study on novel test systems to determine disintegration time of orodispersible films. Journal of Pharmacy and Pharmacology. 2014 Aug 1;66(8):1102–11. doi:10.1111/jphp.12246
17. Lovsin Barle E, Bizec JC, Glogovac M, Gromek K, Winkler GC. Determination and application of the permitted daily exposure (PDE) for topical ocular drugs in multipurpose manufacturing facilities. Pharm Dev Technol. 2018 Mar 16;23(3):225–30. doi:10.1080/10837450.2017.1312442
18. Krampe R, Visser JC, Frijlink HW, Breitkreutz J, Woerdenbag HJ, Preis M. Oromucosal film preparations: points to consider for patient centricity and manufacturing processes. Expert Opin Drug Deliv. 2016 Apr 2;13(4):493–506. doi:10.1517/17425247.2016.1118048
19. Walsh J, Cram A, Woertz K, Breitkreutz J, Winzenburg G, Turner R, et al. Playing hide and seek with poorly tasting paediatric medicines: Do not forget the excipients. Adv Drug Deliv Rev. 2014 Jun;73:14–33. doi:10.1016/j.addr.2014.02.012
20. Garsuch V, Breitkreutz J. Comparative investigations on different polymers for the preparation of fast-dissolving oral films. Journal of Pharmacy and Pharmacology. 2010 Apr 1;62(4):539–45. doi:10.1211/jpp.62.04.0018
21. Vuddanda PR, Montenegro-Nicolini M, Morales JO, Velaga S. Effect of plasticizers on the physico-mechanical properties of

pullulan based pharmaceutical oral films. European Journal of Pharmaceutical Sciences. 2017 Jan;96:290–8. doi:10.1016/j.ejps.2016.09.011
22. Repka MA, Gutta K, Prodduturi S, Munjal M, Stodghill SP. Characterization of cellulosic hot-melt extruded films containing lidocaine. European Journal of Pharmaceutics and Biopharmaceutics. 2005 Jan;59(1):189–96. doi:10.1016/j.ejpb.2004.06.008
23. Irfan M, Rabel S, Bukhtar Q, Qadir MI, Jabeen F, Khan A. Orally disintegrating films: A modern expansion in drug delivery system. Saudi Pharmaceutical Journal. 2016 Sep;24(5):537–46. doi:10.1016/j.jsps.2015.02.024
24. Miro A, d'Angelo I, Nappi A, La Manna P, Biondi M, Mayol L, et al. Engineering poly(ethylene oxide) buccal films with cyclodextrin: A novel role for an old excipient? Int J Pharm. 2013 Aug;452(1–2):283–91. doi:10.1016/j.ijpharm.2013.05.030
25. Fernandes FP, Fortes AC, da Cruz Fonseca SG, Breitkreutz J, Ferraz HG. Manufacture and Characterization of Mucoadhesive Buccal Films Based on Pectin and Gellan Gum Containing Triamcinolone Acetonide. Int J Polym Sci. 2018 Jul 19;2018:1–10. doi:10.1155/2018/2403802
26. PURI V, SHARMA A, MAMAN P, RATHORE N, SINGH I. OVERVIEW OF MUCOADHESIVE BIOPOLYMERS FOR BUCCAL DRUG DELIVERY SYSTEMS. International Journal of Applied Pharmaceutics. 2019 Oct 14;18–29. doi:10.22159/ijap.2019v11i6.35438
27. Drašković M, Medarević D, Aleksić I, Parojčić J. *In vitro* and *in vivo* investigation of taste-masking effectiveness of Eudragit E PO as drug particle coating agent in orally disintegrating tablets. Drug Dev Ind Pharm. 2017 May 4;43(5):723–31. doi:10.1080/03639045.2016.1220572
28. Cilurzo F, Cupone IE, Minghetti P, Selmin F, Montanari L. Fast dissolving films made of maltodextrins. European Journal of Pharmaceutics and Biopharmaceutics. 2008 Nov;70(3):895–900. doi:10.1016/j.ejpb.2008.06.032
29. Kathpalia H, Gupte A. An Introduction to Fast Dissolving Oral Thin Film Drug Delivery Systems: A Review. Curr Drug Deliv. 2013 Nov 31;10(6):667–84. doi:10.2174/15672018100613112515024 9
30. Preis M, Pein M, Breitkreutz J. Development of a Taste-Masked Orodispersible Film Containing Dimenhydrinate. Pharmaceutics. 2012 Oct 26;4(4):551–62. doi:10.3390/pharmaceutics4040551
31. Sohi H, Sultana Y, Khar RK. Taste Masking Technologies in Oral Pharmaceuticals: Recent Developments and Approaches. Drug Dev Ind Pharm. 2004 Jan 25;30(5):429–48. doi:10.1081/DDC-120037477
32. Bhise K, Shaikh S, Bora D. Taste Mask, Design and Evaluation of an Oral Formulation Using Ion Exchange Resin as Drug Carrier. AAPS PharmSciTech. 2008 Jun 6;9(2):557–62. doi:10.1208/s12249-008-9056-6
33. Zheng X, Wu F, Hong Y, Shen L, Lin X, Feng Y. Developments in Taste-Masking Techniques for Traditional Chinese Medicines. Pharmaceutics. 2018 Sep 12;10(3):157. doi:10.3390/pharmaceutics10030157
34. Patel AR, Vavia PR. Preparation and in vivo evaluation of SMEDDS (self-microemulsifying drug delivery system) containing fenofibrate. AAPS J. 2007 Sep;9(3):E344–52. doi:10.1208/aapsj0903041
35. Repka MA, Bandari S, Kallakunta VR, Vo AQ, McFall H, Pimparade MB, et al. Melt extrusion with poorly soluble drugs – An integrated review. Int J Pharm. 2018 Jan;535(1–2):68–85. doi:10.1016/j.ijpharm.2017.10.056
36. Borges AF, Silva C, Coelho JFJ, Simões S. Oral films: Current status and future perspectives II — Intellectual property, technologies and market needs. Journal of Controlled Release. 2015 May;206:108–21. doi:10.1016/j.jconrel.2015.03.012
37. Susarla R, Sievens-Figueroa L, Bhakay A, Shen Y, Jerez-Rozo JI, Engen W, et al. Fast drying of biocompatible polymer films loaded with poorly water-soluble drug nano-particles via low temperature forced convection. Int J Pharm. 2013 Oct;455(1–2):93–103. doi:10.1016/j.ijpharm.2013.07.051
38. Maniruzzaman M, Boateng JS, Snowden MJ, Douroumis D. A Review of Hot-Melt Extrusion: Process Technology to Pharmaceutical Products. ISRN Pharm. 2012 Dec 27;2012:1–9. doi:10.5402/2012/436763
39. Pacheco MS, Barbieri D, da Silva CF, de Moraes MA. A review on orally disintegrating films (ODFs) made from natural polymers such as pullulan, maltodextrin, starch, and others. Int J Biol Macromol. 2021 May;178:504–13. doi:10.1016/j.ijbiomac.2021.02.180

40. Morath B, Sauer S, Zaradzki M, Wagner AH. Orodispersible films – Recent developments and new applications in drug delivery and therapy. Biochem Pharmacol. 2022 Jun;200:115036. doi:10.1016/j.bcp.2022.115036
41. Sandler N, Määttänen A, Ihalainen P, Kronberg L, Meierjohann A, Viitala T, et al. Inkjet printing of drug substances and use of porous substrates- towards individualised dosing. J Pharm Sci. 2011 Aug;100(8):3386–95. doi:10.1002/jps.22526
42. Goyanes A, Buanz ABM, Basit AW, Gaisford S. Fused-filament 3D printing (3DP) for fabrication of tablets. Int J Pharm. 2014 Dec;476(1–2):88–92. doi:10.1016/j.ijpharm.2014.09.044
43. Elbl J, Gajdziok J, Kolarczyk J. 3D printing of multilayered orodispersible films with in-process drying. Int J Pharm. 2020 Feb;575:118883. doi:10.1016/j.ijpharm.2019.118883
44. Preis M, Knop K, Breitkreutz J. Mechanical strength test for orodispersible and buccal films. Int J Pharm. 2014 Jan;461(1–2):22–9. doi:10.1016/j.ijpharm.2013.11.033
45. Garsuch V, Breitkreutz J. Novel analytical methods for the characterization of oral wafers. European Journal of Pharmaceutics and Biopharmaceutics. 2009 Sep;73(1):195–201. doi:10.1016/j.ejpb.2009.05.010
46. Dziemidowicz K, Jin J, Ranmal SR, Piumpongsuk S, Aspinall S, Serpell CJ, et al. Characterization and sensory evaluation of placebo OrPhyllo ™ orodispersible films as a versatile pediatric drug delivery platform. Drug Dev Ind Pharm. 2025 Jul 2;1–11. doi:10.1080/03639045.2025.2521664
47. Visser JC, Woerdenbag HJ, Hanff LM, Frijlink HW. Personalized Medicine in Pediatrics: The Clinical Potential of Orodispersible Films. AAPS PharmSciTech. 2017 Feb 4;18(2):267–72. doi:10.1208/s12249-016-0515-1
48. Kwak HH, Shim WS, Choi MK, Son MK, Kim YJ, Yang HC, et al. Development of a sustained-release recombinant human growth hormone formulation. Journal of Controlled Release. 2009 Jul;137(2):160–5. doi:10.1016/j.jconrel.2009.03.014
49. Borges AF, Silva BMA, Silva C, Coelho JFJ, Simões S. Hydrophobic polymers for orodispersible films: a quality by design approach. Expert Opin Drug Deliv. 2016 Oct 2;13(10):1357–74. doi:10.1080/17425247.2016.1218458
50. Visser JC, Woerdenbag HJ, Hanff LM, Frijlink HW. Personalized Medicine in Pediatrics: The Clinical Potential of Orodispersible Films. AAPS PharmSciTech. 2017 Feb 4;18(2):267–72. doi:10.1208/s12249-016-0515-1
51. Bagde S, Xi X, Boyce H, Kim MJ. Evaluation of orally disintegrating tablets: regulatory pathways, administration practices and harmonization of bioequivalence study design. AAPS Open. 2026 Jan 19;12(1):2. doi:10.1186/s41120-025-00138-y
52. Yu LX, Amidon G, Khan MA, Hoag SW, Polli J, Raju GK, et al. Understanding Pharmaceutical Quality by Design. AAPS J. 2014 Jul 23;16(4):771–83. doi:10.1208/s12248-014-9598-3
53. Yahyaei M, Mehrnejad F, Naderi-manesh H, Rezayan AH. Follicle-stimulating hormone encapsulation in the cholesterol-modified chitosan nanoparticles via molecular dynamics simulations and binding free energy calculations. European Journal of Pharmaceutical Sciences. 2017 Sep;107:126–37. doi:10.1016/j.ejps.2017.07.007
54. Patel VF, Liu F, Brown MB. Advances in oral transmucosal drug delivery. Journal of Controlled Release. 2011 Jul;153(2):106–16. doi:10.1016/j.jconrel.2011.01.027
55. Nair AB, Kumria R, Harsha S, Attimarad M, Al-Dhubiab BE, Alhaider IA. In vitro techniques to evaluate buccal films. Journal of Controlled Release. 2013 Feb;166(1):10–21. doi:10.1016/j.jconrel.2012.11.019
56. Gittings S, Turnbull N, Henry B, Roberts CJ, Gershkovich P. Characterisation of human saliva as a platform for oral dissolution medium development. European Journal of Pharmaceutics and Biopharmaceutics. 2015 Apr;91:16–24. doi:10.1016/j.ejpb.2015.01.007
57. Suresh J, Aravindaraj N, Krishnaswami V, Kandasamy R. Oral film technology: a perspective on translational research and clinical studies. Macromol Res. 2023 Oct 26;31(10):917–32. doi:10.1007/s13233-023-00185-y
58. Noda Y, Fujii K, Fujii S. Corrigendum to “Critical evaluation of cadexomer-iodine ointment and povidone-iodine sugar ointment” [Int. J. Pharm. 372 (2009) 85–90]. Int J Pharm. 2009 Jul;377(1–2):215. doi:10.1016/j.ijpharm.2009.01.027
59. Janßen EM, Schliephacke R, Breitenbach A, Breitkreutz J. Drug-printing by flexographic printing technology—A new manufacturing process for orodispersible films. Int J

Pharm. 2013 Jan;441(1–2):818–25. doi:10.1016/j.ijpharm.2012.12.023
60. Muddineti OS, Ghosh B, Biswas S. Current trends in using polymer coated gold nanoparticles for cancer therapy. Int J Pharm. 2015 Apr;484(1–2):252–67. doi:10.1016/j.ijpharm.2015.02.038
61. Boateng JS, Matthews KH, Stevens HNE, Eccleston GM. Wound Healing Dressings and Drug Delivery Systems: A Review. J Pharm Sci. 2008 Aug;97(8):2892–923. doi:10.1002/jps.21210
62. Castro PM, Fonte P, Sousa F, Madureira AR, Sarmento B, Pintado ME. Oral films as breakthrough tools for oral delivery of proteins/peptides. Journal of Controlled Release. 2015 Aug;211:63–73. doi:10.1016/j.jconrel.2015.05.258