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Oral thin film: An emerging plat form for targeted drug delivery system an overview

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Abstract
Oral thin films (OTFs) represent a revolutionary and highly versatile platform in modern pharmaceuticals, moving beyond traditional dosage forms like tablets and capsules. These ultra-thin, flexible polymeric films are designed to rapidly dissolve or adhere within the oral cavity, offering a superior method for drug administration, particularly for patients with dysphagia, such as pediatric, geriatric, and mentally challenged individuals. The unique characteristics of OTFs, including their ease of use, convenience, and non-invasive nature, significantly improve patient compliance and therapeutic outcomes. This review explores OTFs as an emerging platform for targeted drug delivery. By leveraging the rich vascular network of the oral mucosa, OTFs facilitate rapid absorption of active pharmaceutical ingredients (APIs) directly into the systemic circulation, effectively bypassing first-pass metabolism and enhancing drug bioavailability. The technology can be further tailored to specific therapeutic needs, with various types of films, including fast-dissolving films for immediate-release and mucoadhesive films for sustained-release or local action. Advanced formulation techniques, incorporating novel polymers, nanotechnology, and even 3D printing, are expanding the capabilities of OTFs to deliver a broader range of drug candidates, including poorly soluble drugs, proteins, and peptides. Despite challenges such as moisture sensitivity and limited drug loading capacity, ongoing research is paving the way for the development of "smart" films that can be personalized for individual patients. This review highlights the immense potential of OTFs to revolutionize drug delivery, not only by improving patient experience but also by offering a strategic platform for targeted, efficient, and precise therapeutic intervention.

Keywords: Oral Thin Films (OTFs), pediatric patients, geriatric patients, targeted delivery

Introduction
Oral thin films (OTFs) represent a revolutionary, patient-centric advancement in drug delivery. OTFs are ultra-thin, flexible polymeric strips that dissolve rapidly upon contact with saliva, offering a discreet and fast-acting alternative than a tradisional dosage form like tablets and capsules, particularly valuable for children and elderly patients [1]. OTFs are designed to disintegrate and dissolve within seconds in the oral cavity typically without requiring water, chewing, swallowing and release the active pharmaceutical ingredient (API) for local or systemic absorption via the oral mucosa [2]. the idea of fast-dissolving dosage forms taken from the orally disintegrating tablets (ODTs), OTFs refine this concept by offering a larger surface area for quicker dissolution, enhanced flexibility, and greater comfort making them a superior alternative to ODTs [3]. By dissolving in buccal, sublingual, or palatal mucosa, OTFs enable direct absorption into systemic circulation bypassing the gastrointestinal tract and avoiding first-pass hepatic metabolism thus enhancing bioavailability, accelerating onset of action, and potentially reducing dosage and side effects [4]. OTFs can be engineered to mask bitter-tasting APIs enhancing acceptability in pediatric populations with their discreet, portable format improving adherence and supporting better therapeutic outcomes [5]. Oral thin films (OTFs) were inspired by transdermal patches and initially developed for breath freshening in the early 2000s. The first popular product was Listerine® PocketPaks, which introduced consumers to dissolving films. Soon after, pharmaceutical applications emerged, such as Zuplenz (ondansetron), the first FDA-approved OTF for nausea.

Since then, OTFs have evolved into drug delivery systems for fast action and improved patient compliance. They are now used for local, systemic, and targeted delivery applications[6].This introductory overview sets the stage for a deeper exploration into the diverse applications, advanced formulation strategies, and future potential of oral thin films as an emerging platform for targeted drug delivery systems [7].

Oral thin films (OTFs) are defined by the U.S. Food and Drug Administration as flexible film strips containing one or more dispersed active pharmaceutical ingredients (APIs), intended to be placed on the tongue for rapid disintegration or dissolution in saliva prior to swallowing [2, 6]. These films are typically 0.2-0.3 mm thick and 15-20 mm in diameter, roughly the size of a postage stamps in size and appearance [2]. The underlying principle of oral thin film (OTF) technology lies in their rapid hydration and dissolution kinetics when exposed to the moist environment of the oral cavity, enabling immediate drug release and absorption [8, 9]. Upon placement on the tongue, sublingual area, or buccal mucosa, oral thin films (OTFs) instantly hydrate via saliva and dissolve rapidly typically within seconds to a minute releasing their active pharmaceutical ingredients (APIs) for immediate local or systemic absorption [9, 10].

Drug Absorption Mechanisms

OTFs facilitate drug delivery through three primary absorption pathways.

Oral Mucosal Absorption

Drugs absorbed through the highly vascularized sublingual or buccal mucosa bypass the gastrointestinal tract and gastric degradation, entering directly into systemic circulation via rich blood vessels. This route avoids first-pass hepatic metabolism, resulting in rapid onset and higher bioavailability especially valuable for drugs prone to liver degradation [8].

Gastrointestinal Absorption

When an OTF dissolves and the drug is swallowed, it follows the classic gastrointestinal (GI) absorption route, where it is absorbed through the intestinal mucosa. This pathway can offer improved bioavailability compared to traditional tablets, particularly when the film dissolves rapidly and the drug is formulated in a hydrophilic polymer matrix that facilitates solubility and increase absorption kinetics [11].

Local Therapeutic Action

Certain OTF formulations are designed for localized effects within the oral cavity, such as antimicrobial or analgesic applications. These films adhere to the mucosa and release their active agents directly at the target site, providing localized therapeutic relief without systemic absorption [12, 13].

Classification of Oral Thin Films (OTFs)

Based on drug release mechanism and site of action:

Flash Release Films

These films disintegrate within seconds upon contact with saliva and are ideal for rapid onset of action. Suitable for emergency drugs, analgesics, and antihistamines [14].

Mucoadhesive Melt-Away Wafers

These are single-or multi-layered films containing mucoadhesive polymers that stick to the buccal mucosa and dissolve gradually, releasing the drug over time [14].

Mucoadhesive Sustained-Release Wafers

These films remain adhered to the mucosal surface for extended periods, allowing sustained release (over hours). Ideal for drugs requiring longer therapeutic windows [14].

Orodispersible vs. Oromucosal Films

- **Orodispersible Films (ODFs):** Quickly disintegrate in saliva without adhesion to mucosa; for systemic action via swallowin [15, 8].
- **Oromucosal Films:** Designed to adhere to oral mucosa and deliver the drug either locally or systemically via transmucosal absorption [8].

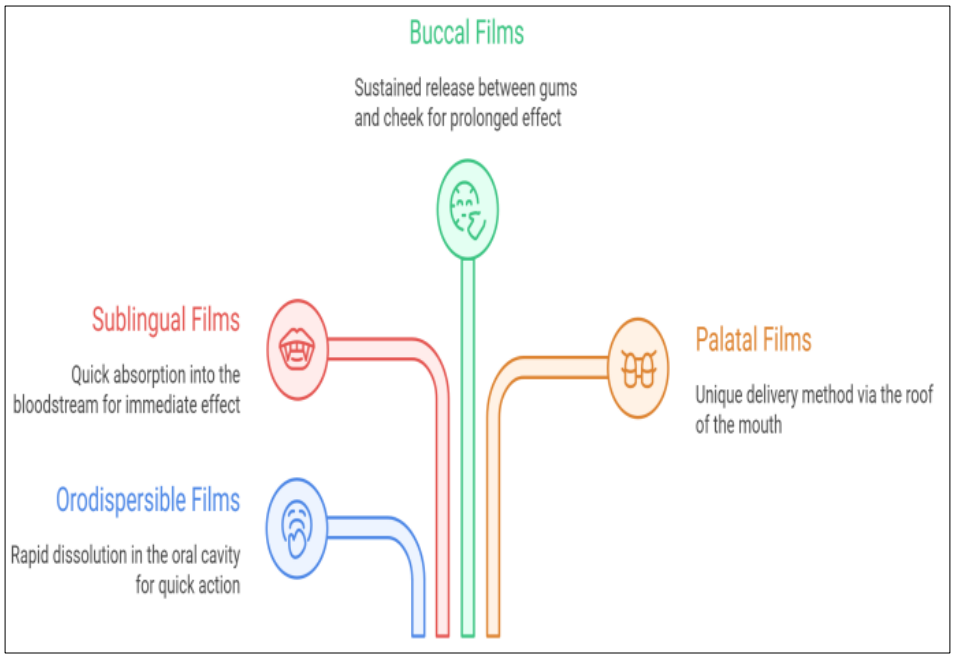

Fig 1: Types oral thin films

Fig 2: Advantages and Clinical Benefits of Oral Thin Films (OTFs)

Advantages and clinical benefits of Oral Thin Films (OTFs)

Patient-Centric Benefits

Enhanced Compliance

OTFs eliminate the need for water and help patients with swallowing difficulties, improving adherence to medication regimens [1, 2, 16].

Rapid Onset

Direct mucosal absorption allows for a faster therapeutic effect compared to conventional oral dosage forms [1, 6, 7].

Portability and Convenience

Compact size and stable packaging make OTFs ideal for travel and emergency use [16, 17].

Taste Masking

Cyclodextrin complexes and polymer coatings effectively mask unpleasant tastes, improving patient acceptability [1, 16].

Pharmacokinetic Advantages

Bypassing First-Pass Metabolism:

Sublingual and buccal routes avoid hepatic metabolism, potentially improving bioavailability [1, 2, 7, 17].

Precise Dosing

Perforated or segmented films allow for accurate dose adjustment and personalized therapy [1, 17].

Improved Bioavailability

The large surface area and rapid dissolution of OTFs enhance absorption of poorly water-soluble drugs [1, 15].

Challenges and Limitations of Oral Thin Films

Technical Challenges

Drug Loading Limitations

OTFs are typically limited to low-dose medications (≤40 mg) due to film thickness constraints [1, 2, 15, 17].

Stability Issues

Films are hygroscopic and susceptible to moisture-induced degradation, requiring specialized packaging [15, 17, 18].

Manufacturing Complexities

Achieving uniform drug distribution and consistent film properties at commercial scale remains challenging [1, 2, 15, 17].

Taste Masking Difficulties

Highly bitter drugs present significant formulation challenges that may not be adequately addressed by conventional taste-masking approaches [15, 17].

Regulatory and Quality Concerns

Lack of Standardized Guidelines

Absence of comprehensive pharmacopeial monographs creates regulatory uncertainty and quality standardization challenges [2].

Limited Drug Compatibility

pH-Sensitive drugs and mucosa-irritating compounds cannot be formulated into OTFs [1, 15, 17].

Dose Termination Impossibility

Once dissolved, dose cannot be retrieved, limiting flexibility in clinical scenarios requiring dose adjustment [1, 15].

Table 1: Material required in oral thin film

Category	Examples	Purpose/Function	Reference
Film Forming Polymers	HPMC (E5, E15), PVA, PVP, Pullulan, Sodium alginate, CMC, Gelatin, Xanthan gum, Maltodextrin, Chitosan, starch, pectin Hydrolyzed Collagen	Forms the base matrix; provides strength and flexibility	[1, 2, 6, 20-22]
Plasticizers	Glycerin, Propylene glycol, PEG 400, Triethyl citrate, Sorbitol, mannitol, diethyl phthalate, tributyl citrate, macrogol, and citric acid esters	Improves flexibility, reduces brittleness	[1, 2, 6, 20-22]

Active Pharmaceutical Ingredients (API)	Ondansetron, Rizatriptan, Domperidone, Sildenafil, Ibuprofen, Clonazepam, also can use herbal extract.	Therapeutic activity	[1, 2, 3, 6, 21, 22]
Sweeteners	Sucralose, Aspartame, Saccharin sodium, Mannitol	Improves palatability	[1, 2, 6, 21, 23]
Flavoring Agents	Mint, Orange, Strawberry, Cherry essence	Enhances patient compliance (especially for pediatrics)	[1, 2, 3, 6, 23]
Saliva Stimulating Agents	Citric acid, Tartaric acid, Malic acid	Enhances disintegration and mouthfeel	[1, 2, 6, 23]
Surfactants	Poloxamer 407, Sodium lauryl sulfate (SLS), Tween 80	Improves wetting, dispersion and solubility of API	[1, 2, 23]
Stabilizers/Preservatives	Methylparaben, Propylparaben, Benzalkonium chloride	Ensures chemical and microbial stability	[1, 2, 6, 21]
Coloring Agents	Titanium dioxide, FD&C dyes	Improves aesthetic appearance	[1, 2, 6, 22, 23]
Disintegrants	Crospovidone, Sodium starch glycolate, Croscarmellose sodium	Accelerates disintegration	[1]
Mucoadhesive Agents	Chitosan, Carbopol, HPMC-K series	Enhances retention at buccal/mucosal site	[1, 23-25]

Manufacturing Technologies

Solvent Casting Method

Solvent casting is the most commonly adopted manufacturing technique for OTFs due to its simplicity, cost-effectiveness, and scalability. The standard steps include: Dissolving polymers in water, ethanol, or mixed solvents. Thorough mixing of the API and excipients. Casting the solution onto flat surfaces to form uniform films4. Evaporation of solvents under controlled temperature and humidity. Cutting and packaging films in moisture-protective materials. This method reliably achieves up to 90% production efficiency and produces films with uniform thickness and consistent drug distribution [1, 2, 22, 26, 28, 29].

Hot Melt Extrusion (HME)

Hot melt extrusion provides a solvent-free manufacturing alternative with advantages including:

Continuous processing capability. Environmental sustainability (no organic solvents) improved drug solubilization for poorly water-soluble compounds. Enhanced stability through amorphous solid dispersion formation [1, 2, 6, 30-32].

The process involves heating drug-polymer blends through extruder barrels, forming molten mass that is shaped and cooled to produce films. Recent studies demonstrate that HME films retain structural and chemical integrity over 12 months when properly packaged [30].

Emerging Technologies

- **Semi-solid Casting:** Involves gel mass formation and controlled drying [2].
- **Rolling Method:** Continuous film formation using roller systems [2].
- **3D Printing:** Enables personalized dosing and complex film architectures [1, 33, 34].
- **Electrospinning:** Produces Nano fiber-based films with enhanced surface area [1, 35, 36].

Targeted Drug Delivery with Oral Thin Films

Oral thin films (OTFs) are utilized to deliver drugs directly through the oral mucosa, allowing for both systemic and localized drug delivery. OTFs offer unique targeting opportunities by enabling:

Direct Systemic Absorption

When placed under the tongue (sublingual) or against the inner cheek (buccal), OTFs allow APIs to be absorbed directly through the mucosa into systemic circulation bypassing gastrointestinal degradation and hepatic first-pass metabolism. This translates into rapid onset of action and enhanced bioavailability [2, 37].

Local therapy in the oral cavity

Some OTFs are formulated as mucoadhesive films designed to adhere to the mucosal surfaces of the mouth (e.g., buccal ulcers, cold sores, tooth pain), enabling localized drug delivery directly to the target tissue. These films maintain prolonged residence at the site, facilitating controlled release of APIs for maximum local therapeutic effect, while minimizing systemic absorption and side effects [1, 2, 38].

Gastrointestinal targeting

Certain OTFs are designed for rapid orodispersal they dissolve on the tongue within seconds, and the released drug is swallowed for intestinal absorption, enabling systemic drug delivery via the gastrointestinal (GI) route [11, 16, 18].

Targeted drug delivery using oral films is primarily achieved by designing the film's formulation to release drugs at specific sites within the oral cavity or gastrointestinal tract, or to enable systemic uptake through the oral mucosa. Approaches and supporting reference articles include.

Site-Specific Drug Delivery within the Mouth

Oral fast-dissolving films (OFDFs) can be formulated to adhere to specific regions of the oral mucosa such as the buccal or sublingual areas enabling targeted local therapy for conditions like periodontal disease or oral pain. This targeted approach enhances local drug concentration while reducing systemic side effects [8, 22, 39].

Systemic Targeting through Mucosal Absorption

Active compounds can be absorbed directly into the bloodstream via the oral or sublingual mucosa, effectively bypassing hepatic first-pass metabolism, thus improving systemic bioavailability [8, 22]. The incorporation of mucoadhesive polymers (e.g., chitosan, HPMC) and nanocarriers such as nanoparticles and liposomes into oral thin films enhances drug permeability, stability, and targeted delivery [40-42].

Gastroprotective and GI Tract Targeting

Oral fast-dissolving films (OFDFs) can be strategically designed to dissolve in the stomach or upper gastrointestinal (GI) tract, enabling site-specific and prolonged drug release for conditions like gastric ulcers or inflammatory bowel disease. Incorporation of nanoparticles within these films enhances mucoadhesion, gastric retention, and controlled release, improving drug localization at diseased GI sites [43-45].

Nanotechnology and Mucoadhesive Polymers

Modern oral films can incorporate nanocarriers such as polymeric nanoparticles, liposomes, and solid lipid nanoparticles, which significantly improve the solubility,

bioavailability, and stability of poorly water-soluble or sensitive drugs [46, 47]. These nanocarriers can be engineered with surface modifications (e.g., PEGylation or ligand conjugation) to enable site-specific targeting post oral or mucosal absorption [48].

Targeted drug delivery mechanisms-mucoadhesive targeting

Oral thin films (OTFs) can be engineered with mucoadhesive properties using polymers like chitosan, carbopol, and sodium alginate, enabling prolonged adhesion to oral mucosal surfaces. This facilitates:

Localized drug concentration at targeted oral sites

- Reduced dosing frequency
- Enhanced therapeutic efficacy for oral pathologies such as mucosal ulcers and periodontal conditions [49, 50].

Types of targets for OTF-Based Drug Delivery

Oral thin films (OTFs) can be formulated to address diverse therapeutic targets based on site-specific delivery:

- **Systemic Disease Management (e.g., pain, migraine, epilepsy, cardiovascular disorders):** Drugs administered via buccal or sublingual mucosa bypass first-pass metabolism and rapidly reach systemic circulation [6, 51].
- **Central Nervous System (CNS) Disorders:** OTFs like diazepam buccal films are particularly effective for seizure emergencies they provide fast, reliable absorption without the need for intravenous access or ingestion [52].
- **Oral and Dental Conditions:** OTFs with mucoadhesive properties deliver drugs directly to the oral mucosa for localized conditions (e.g., ulcers, toothaches, infections), also used for lacal anesthesia increasing local therapeutic concentration while minimizing systemic exposure [53-58].

Pediatric and Geriatric Populations

Oral thin films (OTFs) are particularly advantageous for children and elderly patients who often have difficulty swallowing solid dosage forms. Films dissolve rapidly (typically within one minute), do not require water, and are easy to administer leading to higher patient compliance, rapid therapeutic onset, and improved adherence [59-61].

Nutraceutical and Supplement Delivery

OTFs are increasingly used for nutraceuticals and dietary supplements such as vitamins, herbal extracts, and bioactive peptides because they offer convenient, fast-dissolving delivery, accurate dosing, portability, and enhanced consumer acceptance [62].

Table 2: Common drug can used in OTF

API	Category	reference
Nicotine	Smoking cessation	[1]
Glyceryl trinitrate	Vasodilator	[1, 2]
Zolmitriptan	Antimigraine	[1]
Loratadine	Antihistaminic	[1, 2]
Desloratadine	Antihistaminic	[1, 2]
Diphenhydramine HCl	Antihistaminic	[1, 2]
Loperamide	Antidiarrheal	[1]
Famotidine	Antacid	[1]
Flurazepam	Anxiolytic	[1, 2]
Chlorpheniramine maleate	Antihistaminic	[1, 2]
Acrivastine	Antihistaminic	[1, 2]
Oxycodone	Opioid analgesic	[1, 2]
Dicyclomine	Muscle relaxant	[1]
Omeprazole	Proton pump inhibitor	[1]
Cetirizine	Antihistaminic	[1]
Ketoprofen	Anti-inflammatory	[1]
Levocetirizine + Loratadine	Antihistaminic	[1]
Ketorolac	NSAID	[1, 2]
Indomethacin	NSAID	[1, 2]
Valdecoxib	NSAID	[1, 2]
Piroxicam	NSAID	[1, 2]
Mirtazapine	Antidepressant	[1, 2]
Buspirone	Anxiolytic	[1, 2]
Carvedilol	Beta blocker	[1, 2]
Diazepam	Sedative	1,63
Etophylline	Bronchodilator	[64]
Atenolol	Beta blocker	[65]
Glibenclamide	Antidiabetes	[66]
Phenobarbital	antiepileptic	[67]
Midazolam	antiepileptic	[68]
Benzocaine	Local Anesthetics	[69, 70]

Evaluation and Characterization Methods of OTFs

Physical Characterization

- **Thickness Uniformity:** Checked using digital calipers or micrometers for consistent dosing across batches [1, 2, 26, 71].

- **Weight Variation:** Assessed by weighing multiple individual film units [1, 2, 26, 71].
- **Tensile Strength:** Measured using tensile-testing instruments to determine mechanical durability [1, 2, 26, 71].
- **Folding Endurance:** Determined by repeatedly folding films until visible cracking occurs [1, 2, 26, 71].

Chemical Analysis

- **Drug Content Uniformity:** Ensured via High-Performance Liquid Chromatography (HPLC) to assess API distribution [1, 2, 26, 71].
- **Moisture Content:** Measured gravimetrically or with moisture analyzers (e.g. Karl Fischer) [1, 26, 71].
- **Surface pH:** Checked using wetted pH electrode on film surface to avoid mucosal irritation [1, 2, 26, 71].

Performance Testing

- **Disintegration Testing:** Methods include modified USP disintegration apparatus, petri-dish method, texture analyzer, and PT-ODF rigs [1, 26, 71].
- **Dissolution Testing:** Conducted using modified small-volume dissolution setups appropriate for thin films [1, 26].

Table 3: Marketed available oral thin film

Trade Name	API	Therapeutic Use	Reference
Listerine® PocketPaks®	Menthol	Mouth freshener / Antiseptic	[1, 2, 23]
Sudafed PE®	Phenylephrine	Nasal decongestant	[1, 2, 23]
Gas-X Thin Strips®	Simethicone	Antiflatulent / Relief from gas	[1, 2, 23]
Theraflu® Day Time Thin Strips	Dextromethorphan, Diphenhydramine	Cough and cold relief	[1, 2, 23]
Suppress® Cough Strips	Menthol	Cough suppressant / Soothing throat relief	[1, 2, 23]
Chloraseptic® Sore Throat Strips	Benzocaine	Local anesthetic for sore throat	[1, 2, 23]
Pedia-Lax™ Quick Dissolve Strip	Sennoside	Pediatric laxative	[1, 2, 23]
Benadryl® Allergy Quick Dissolve Strips	Diphenhydramine	Antihistamine / Allergy relief	[1, 2, 23]
Sildenafil Orodispersible Film	Sildenafil	Erectile dysfunction	[1, 6]
Zuplenz®	Ondansetron	Antiemetic (nausea/vomiting)	[1, 6]
Risperidone HEXAL® ODF	Risperidone	Antipsychotic / Schizophrenia, bipolar	[1, 6]

Market Growth Dynamics

The global oral thin films (OTFs) market demonstrates a robust growth trajectory, driven by:

Increasing prevalence of chronic diseases requiring long-term medication adherence [1]. Growing elderly population with swallowing difficulties (dysphagia) [1, 2]. Rising demand for patient-friendly and non-invasive drug delivery systems [1, 2, 15]. Ongoing technological advancements in OTF formulation and scalable manufacturing [72]. Due to their ease of use and strong effectiveness, oral thin-film drugs have become very popular in the pharmaceutical market. Both well-established and new pharma companies are showing great interest in this technology. In fact, these products have seen impressive sales, especially in the U.S. and Europe. Back in 2007, the market for oral thin-film drugs was around $500 million, and by 2010, it had already grown to $2 billion. According to a research report, the global thin-film drug market is expected to rise from $7 billion in 2015 to more than $15 billion by the end of 2024 a 117% growth in just 10 years [2].

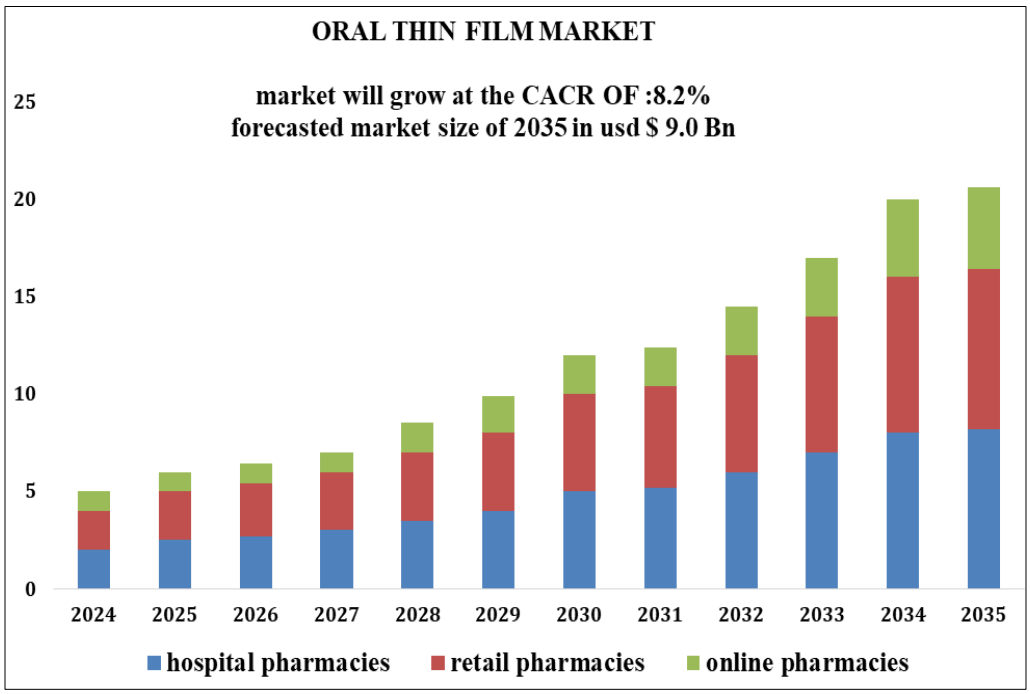

Fig 3: Global oral thin films in market

Future Perspectives and Innovations

- **Nanotechnology Integration:** Nanoparticle-loaded films such as those incorporating lipid-based carriers or polymeric nanocrystals have been shown to significantly enhance the solubility, dissolution rate, and bioavailability of poorly water-soluble drugs [1].

- **3D Printing Technology:** Development of personalized oral thin films (OTFs) with tailored drug combinations and controlled release profiles is being made possible through advances in 3D printing technology [1, 73-75].
- **Smart Films:** Emerging innovations involve integrating sensors, microchips, or RFID systems into oral thin films to enable real-time monitoring of drug administration and improve patient adherence [76].

Therapeutic Expansion

Biologics Delivery via Oral Thin Films

Delivering proteins and peptides through OTFs presents significant challenges due to their large molecular weight, enzymatic degradation, and poor mucosal permeability. However, recent research demonstrates the potential of OTFs as non-invasive delivery platforms for biologics when formulated with stabilizing excipients (e.g., trehalose, mannitol) and permeation enhancers (e.g., bile salts, surfactants, chitosan) [77-79].

Combination Therapies: Multi-Drug Oral Thin Films

Oral thin films (OTFs) are increasingly being developed to deliver multiple active pharmaceutical ingredients (APIs) in a single film. This multi-drug strategy offers enhanced patient convenience, improved medication adherence, and the potential to address polypharmacy in chronic diseases such as hypertension, diabetes, and mental health disorders [79, 80].

Nutraceutical Applications

Oral thin films are increasingly used in the dietary supplement and functional foods market due to their ease of administration, rapid onset of action, and higher consumer acceptability, especially among children and elderly populations. Nutraceuticals like vitamins (e.g., B12, D3), minerals, plant extracts, and probiotics are now formulated into OTFs for improved bioavailability and patient convenience [81-83].

Manufacturing Innovations

- **Continuous Manufacturing:** The adoption of continuous manufacturing for OTFs allows real-time quality monitoring, greater efficiency, reduced production cost, and better product consistency. Technologies like inline near-infrared (NIR) spectroscopy are integrated for real-time process analytical control (PAT), ensuring regulatory compliance and product uniformity [84, 85].
- **Green Manufacturing:** With growing environmental concerns, there's a shift toward eco-friendly manufacturing using biodegradable polymers (e.g., pullulan, HPMC, starch derivatives), solvent-free or aqueous-based methods, and energy-efficient drying systems. These innovations aim to reduce the carbon footprint and make OTFs more sustainable [86].

Conclusion

Oral thin films (OTFs) represent a modern, patient-friendly drug delivery system that offers numerous advantages over conventional dosage forms like tablets and capsules. These films are particularly useful for patients who have difficulty swallowing, such as children, the elderly, and those with neurological conditions. The fast disintegration and absorption of OTFs in the oral cavity allow for rapid onset of action, which is especially beneficial in conditions where immediate relief is needed.

This review has explored the essential aspects of oral thin films, including their types, formulation components, manufacturing techniques, and evaluation methods. Different polymers, plasticizers, and other excipients play a crucial role in determining the film's properties such as flexibility, stability, and drug release. Among various manufacturing techniques, solvent casting remains the most widely used method due to its simplicity and cost-effectiveness.

Recent advancements show promising developments in using OTFs for the delivery of biologics, vaccines, nutraceuticals, and combination therapies. Moreover, the application of green technologies and continuous manufacturing has improved the production process, making it more sustainable and efficient.

Despite some limitations like moisture sensitivity and limited drug loading capacity, the advantages offered by oral thin films including better patient compliance, precise dosing, and the possibility of systemic as well as local drug delivery make them an innovative and valuable tool in modern therapeutics. With ongoing research and technological support, OTFs are expected to play a significant role in the future of drug delivery systems.

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