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Advances in Oral Mucoadhesive Drug Delivery: Enhancing Drug Efficacy and Targeted Delivery

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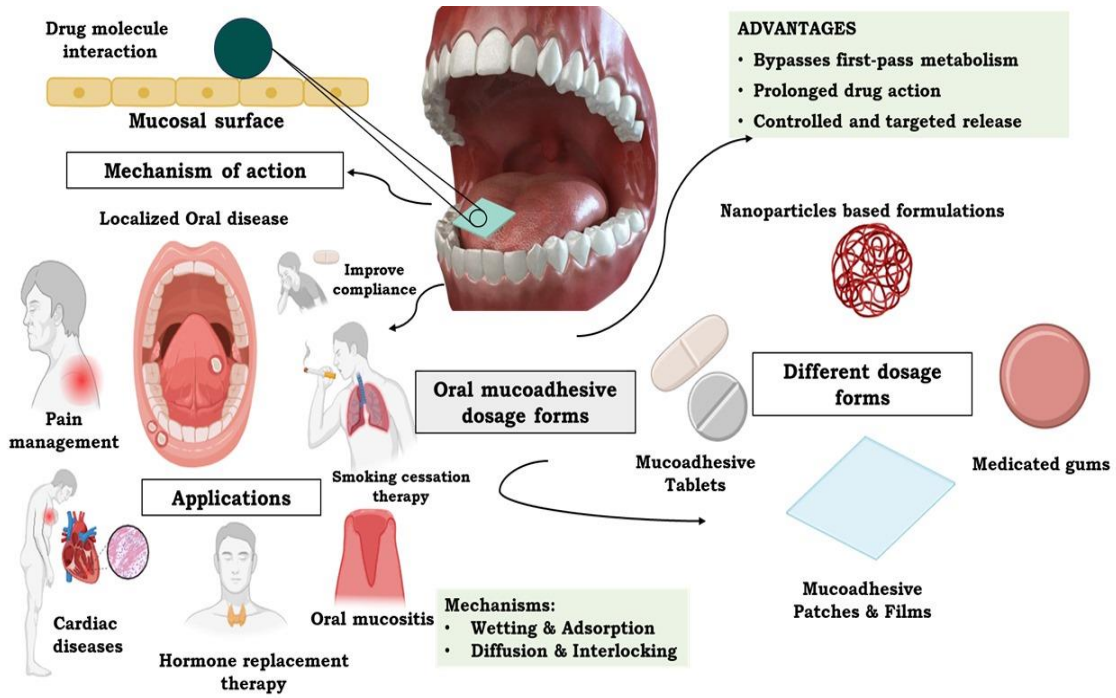
ABSTRACT

Oral mucoadhesive drug delivery systems have sparked significant interest in pharmaceutical research due to their capacity to increase drug bioavailability, prolong retention at the administration site, and improve patient adherence. These systems use bioadhesive polymers that stick to mucosal surfaces, allowing for controlled drug release and focused therapy. Various dosage forms, such as buccal tablets, patches, films, nanoparticles, and medicated gums, have been created to improve medication absorption and therapeutic impact. The success of these formulations is heavily reliant on mucoadhesion mechanisms such wetting, adsorption, and diffusion interlocking. However, despite their benefits, issues such as mucosal variability, formulation stability, possible toxicity, and patient acceptability must be addressed. Continuous advances in polymer science and novel drug delivery technologies refine mucoadhesive systems, paving the path for more effective therapeutic applications. Two fundamental problems in new drug development remain low water solubility and poor oral bioavailability. This drug delivery method has grown in popularity in recent years due to its ability to overcome issues commonly associated with traditional drug delivery systems, such as first-pass metabolism, enzymatic degradation, gastrointestinal toxicity, instability in extreme pH conditions, and low bioavailability.

Keywords: oral mucoadhesive, bioadhesive polymers, First pass metabolism, Controlled drug delivery, Buccal drug delivery.

GRAPHICAL ABSTRACT



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1. INTRODUCTION

The oral cavity's mouth floor and the inside of the cheeks are the locations where drugs are administered. Both the buccal and sublingual gums are gingival. A medication is delivered when it is released into the oral cavity in a dose form. [1] Some kind of dosage form that is present in the oral cavity is necessary for drug distribution. Through the mucosa, this then spreads into the local blood circulation before continuing on to the systemic blood circulation.[2] The creation of effective drug delivery systems has become a key component of pharmaceutical research due to the desire to increase patient compliance, decrease side effects, and improve therapeutic outcomes of medications. Given its potential to fundamentally alter the way medications are delivered through the oral cavity, these systems have attracted more interest among the various drug administration techniques.[3] The buccal mucosa is easily accessible, this method of administration is very practical for patients, especially those who may have trouble swallowing, as well as for pediatric and geriatric populations and those with gastrointestinal disorders. The main concept underlying mucoadhesive buccal drug delivery devices is the development of formulations that can attach to buccal mucosa. Overall, the numerous advantages of oral mucoadhesive drug delivery system is an alternative to traditional oral drug delivery systems. This paper aims to explore the different types of oral mucoadhesive systems, polymers used for better drug delivery, applications, evaluation parameters and future perspectives to improve drug efficacy through oral mucoadhesive drug delivery.

1.1 Structure and anatomy of oral cavity

Mouth, usually referred to as the oral cavity, is a complicated organ that is necessary for speaking, breathing, and above all ingesting food and the initial phases of its digestion. Both general knowledge and applications in medicine or dentistry depend on an understanding of its anatomy and structure.[5] The oral cavity's primary components include the aperture of the oral cavity is formed by the upper and lower lips. The tongue is a muscular organ that has taste receptors to detect flavours. It is necessary for controlling food when speaking and chewing, because teeth break food down into little bits. The gingiva, or gums, are the pink or reddish tissues that envelop and support the teeth. The buccal mucosa has three distinct layers: epithelium, basement membrane, and connective tissue. [6] The epithelium is the outermost layer that lines the basement membrane, which is supported by the connective tissue beneath it. Within the oral cavity, two types of epithelium are present. The non-keratinized epithelium covers areas such as the soft palate, ventral surface of the tongue, alveolar mucosa, vestibule, lips, and cheeks. In contrast, the keratinized epithelium is found in more rigid regions, including the hard palate and other less flexible areas. Epithelial cells originate as basal cells and gradually undergo structural modifications, changing shape and expanding as they mature and migrate outward. [7]

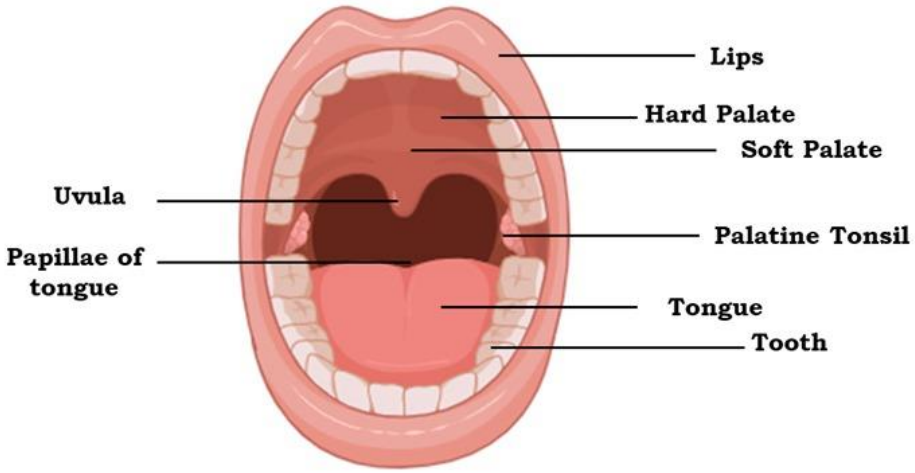

Fig 1. Structure of oral cavity [10]

1.2 Mucus Layer Composition

The soft tissue lining the body's cavities and internal organs, such as the ear, the respiratory system, the gastrointestinal tract, and the eye, is known as the mucosal surface. When mucus is present, this surface is in charge of creating an adhesive interface.[8] Mucus is a thin, continuous gel blanket that is transparent and viscous and adheres to the mucosal surface's epithelial layer. It is possible for the epithelia to be stratified, multilayered, or single-layered. The epithelia, which are unique exocrine glands that release mucus, are lined with goblet cells. Humans have mucous layers that range in thickness from 50 to 450 µm. [9] The mucus layer is made up of 95% water, 0.5-5% glycoproteins and lipids, 1% mineral salts, and 0.5-1% free proteins. Glycoproteins in mucus are high-

molecular-weight proteins that include oligosaccharide units made up of 8-10 monosaccharides each. These components contribute to the structural and functional features of mucus, playing an important role in the adherence and protection of mucosal surfaces. A glycoprotein called mucin has a single-chain amino acid backbone and branching oligosaccharide chains made of galactose, fructose, and N-acetylglucosamine. [10]

1.3 The Ideal Buccal Drug Delivery System Characteristics [11,12]

- The drug must be released in a controlled manner.
- Release the drug in a single path into the mucosa.
- Patients should not experience irritation or pain.
- Ensure a balance of lipophilicity and hydrophilicity.
- It is recommended that the patient remain at the attachment site for a few hours.
- Mucoadhesive tablets have a half-life of roughly two to seven hours.
- Their dosage range is 20 mg to 100 mg.
- They should be easy to absorb and present no barriers to released drug.

1.4 Mucoadhesive buccal drug delivery systems have the following advantages [12,13,14]

- Certain medications can be supplied through buccal route due to stomach acidity.
- Drugs are absorbed through passive diffusion.
- High absorption rates are achieved through tight contact with the absorbent membrane surface.
- Long-lasting drug release
- Suitable for traumatized or unconscious patients
- High bioavailability due to bypassing first-pass metabolism
- Simple to deliver and discontinue in emergency situations.
- Quick drug absorption and prevention of first-pass metabolism.
- Long lasting therapeutic effects and fewer effects A lower dosage is needed.
- A higher level of patient compliance.
- Preventing irritation of the stomach.
- Suitable for Drugs That Are Sensitive
- Flexibility.
- Increased effectiveness of treatment.
- A substitute for injections
- The Potential for Self-Management

1.5 Factors Affecting Mucoadhesion

1.5.1 Mucoadhesive Material Properties

- Molecular Weight- Because of their stronger contacts with the mucosal surface and more substantial chain entanglements, polymers with a greater molecular weight typically exhibit superior mucoadhesion.

- Flexibility- Flexible polymer chains enhance mucoadhesion by allowing for better penetration of the mucin network on the mucosal surface.

- Hydrophilicity- Hydrophilic polymers can suck water from the mucosal surface, resulting in swelling and better mucosal contact.

- Charge- Ionic interactions allow ionic polymers to interact more strongly with the mucin, which is similarly charged. Because of their interactions with negatively charged mucin, cationic polymers often have better mucoadhesion.

- Polymers with significant cross-linking may have lower mucoadhesion due to their reduced flexibility and expansion. [13]

1.5.2 Mucosal Surface Properties

- Mucoadhesion can be reduced by high mucin turnover because the attached material may be removed more quickly.

- Greater mucus layer thickness can serve as a barrier as well as a more significant surface for adhesion.

- Mucin Composition: Differences in mucin structure and composition might affect mucoadhesive interactions.

1.5.3 Environmental Conditions

- pH- The pH of the surroundings can affect the ionization of the mucoadhesive polymer and mucosal surface.

- Adequate hydration enhances swelling of the mucoadhesive polymer, leading to better adhesion.

- Food, saliva, and other substances can affect mucoadhesion by creating a barrier or changing the mucosal surface properties. [14]

1.5.4 Biochemical Aspects

- disorders or Diseases: A number of disorders or diseases can change the mucosal surface's characteristics, which might impact mucoadhesion. [15]

2. MECHANISM OF MUCOADHESION

Mucoadhesion is a phenomenon that occurs at the interface between two materials, where one is a synthetic substance, such as a mucoadhesive polymer, and the other is the mucin layer present on the mucosal tissue. These two surfaces adhere to each other due to interfacial forces of attraction, which enable prolonged contact and enhanced drug retention. The term "mucoadhesive" describes a specially designed material that has the ability to interact with mucous membranes and remain attached for an extended period. This adhesive property is particularly beneficial in drug delivery systems, as it allows for controlled and sustained drug release, improving therapeutic effectiveness and patient compliance. By forming a stable interaction with the mucosal surface, mucoadhesive materials help optimize drug absorption, ensuring better bioavailability and prolonged treatment effects. [6]

- **Contact Stage:** When a mucoadhesive material makes contact with the mucous membrane, a close interaction occurs, leading to the formation of a moist interface between the two surfaces. This moisture plays a crucial role in facilitating adhesion, as the mucus secreted by the mucosal membrane spreads over the mucoadhesive material, allowing it to adhere effectively. The wetting process enhances the material's ability to interact with the mucosal surface at a molecular level, enabling the formation of physical and chemical bonds. This initial stage of adhesion is essential for ensuring that the mucoadhesive system remains in place, allowing for controlled drug release and prolonged therapeutic effects. The degree of wetting largely depends on factors such as the hydrophilicity of the polymer, the mucus composition, and the physiological conditions of the mucosal surface. Effective wetting is critical for optimizing the performance of mucoadhesive drug delivery systems, ensuring better bioavailability and improved patient outcomes. [6, 16]

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- **Consolidation stage:** The process of mucoadhesion progresses beyond initial contact to a phase known as consolidation, during which a strong and lasting bond is established between the mucoadhesive material and the mucous membrane. This prolonged adhesion occurs due to a combination of physical and chemical interactions, including hydrogen bonding, van der Waals forces, electrostatic interactions, and polymeric chain entanglement. These interactions ensure that the mucoadhesive material remains attached to the mucosal surface for an extended period, allowing for sustained drug release and improved therapeutic efficacy. [16, 17]

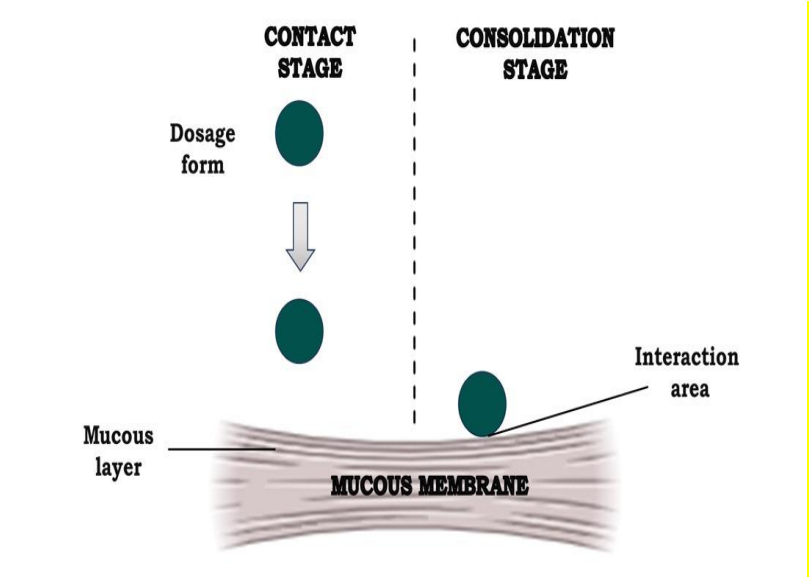

Fig 2. Mechanism of Mucoadhesion[18]

Bioadhesion/Mucoadhesion [16]

Bioadhesion is a phenomenon in which a bond is established between two biological surfaces or between a synthetic material and a biological surface. This interaction plays a significant role in various medical and pharmaceutical applications, particularly in drug delivery systems. In the context of bioadhesive drug delivery, the term refers to the ability of natural or synthetic polymers to adhere to soft tissues, such as the mucosal linings of the gastrointestinal tract, oral cavity, nasal passages, and other mucosal surfaces. When the adhesive interaction specifically involves the mucus layer covering the mucosal surface, the term "mucoadhesion" is used. In such cases, bioadhesion and mucoadhesion are often used interchangeably since both involve the attachment of a substance to a biological surface through various physiochemical interactions.

2.1 Theories of Mucoadhesion

2.1.1 Wetting theory

In this concept, adhesives may adhere to surface defects and attach themselves there. It works with low viscosity liquid or mucoadhesive systems. The spread ability of mucoadhesive polymers on biological surfaces is explained by this idea. The affinity for the surface can be determined by measuring the contact angle.

2.1.2 Adsorption Theory

The bioadhesion mechanism is explained by this theory, which explains the involvement of both primary and secondary chemical bonds. Both the mucin-containing surface and the medication delivery mechanism possesses a surface energy of its own. Surface energy causes adhesion when they come into contact, which leads to the creation of two different kinds of chemical bonds. Permanent bonds are created by primary chemical bonds like covalent bonds, which are strong by nature, whereas semi-permanent bonds are created by secondary chemical bonds that involve Vander-Waals forces, hydrophobic interactions, and hydrogen bonds, which are weak by nature. [17]

2.1.3 Electronic theory

This theory explains the difference in the electronic structure of mucin surfaces or bioadhesive systems leads to the achievement of an electronic gradient. When the two systems (the bioadhesive system and the mucin surface) come into contact with one another, electrons are transferred because of this electrical structural difference. As a result of the electron transfer, an electronic bi-layer arises at the interface of the two surfaces. This interfacial bi-layer provides an attractive force at the interface between the two surfaces, which may result in effective mucoadhesion.

2.1.4 Diffusion Interlocking Theory

In this theory, the drug delivery system's polymeric chains and the mucus membrane, specifically the glycol proteins, form a mechanical link. The drug delivery system's polymeric chain penetrates the glycoprotein network when two surfaces come into close contact. This theory states that both polymeric chains' diffusion coefficients essentially.

determine bioadhesion. The inter movement of polymeric chains can also be affected by temperature, chain flexibility, cross linking density, and molecular weight. The bioadhesive medium should be suitably soluble in glycoprotein to produce effective mucoadhesion and provide good bioadhesion. [18]

2.1.5 Mechanical Theory

This theory explains, adhesion occurs when a mucoadhesive fluid fills the rough surface; even while these irregularities expand the area of the contact that is available for interaction, they are thought to be the most significant stage in the process.

2.1.6 Fracture Theory

The fracture theory has perhaps described to be the most useful theory for testing mucoadhesion using mechanical observations. After adhesion, this theory examines the forces needed to separate two surfaces. [19]

3. CHALLENGES IN MUCOADHESIVE DRUG DELIVERY [20,21]

3.1 Variability in mucosal surfaces.

- Heterogeneity: Different mucosal surfaces have distinct shapes and compositions that influence medicine absorption and adherence.

- Rapid mucus turnover can eliminate the mucoadhesive formulation before full medication absorption.

3.2 Stability of Formulation

Chemical and Physical Stability: It can be challenging to keep the drug and mucoadhesive polymers stable during storage and after administration.

pH Sensitivity: The adhesive qualities and medication release profile of several mucoadhesive polymers can be changed by pH variations.

3.3 Toxicity and Irritation

- Local Irritation: Prolonged contact with the mucosa may result in tissue damage or irritation.

- Toxicity: Certain mucoadhesive polymers or the byproducts of their breakdown may be harmful or result in adverse reactions.

3.4 Patient compliance

- Patients may experience discomfort when adhesive formulation is present in their mouth surface.

- Unpleasant taste and odour might limit patient compliance with the formulation.

3.5 Environmental Factors

- Mucosal surface moisture has a substantial influence on the formulation's adhesion qualities.
- Enzymatic Activity: Mucosal enzymes can break down drugs and sticky polymers.

3.6 Manufacturing Challenges

- Complexity: Developing and producing these formulations will be more challenging and high cost than traditional dosage forms.
- Market potential: Achieving consistent performance and quality in large-scale production will be challenging.

4. THE KEY COMPONENTS OF AN ORAL DRUG ADMINISTRATION SYSTEM

4.1 Drugs: Before developing mucoadhesive dosage forms, it's important to determine whether the discharge will be fast or slow. Choosing the right drug for buccoadhesive drug delivery systems requires careful consideration of its pharmacokinetic features. The medication needs to possess the following,

- **Deliver the drug in an exact and consistent dose.**
- Ensuring that the treatment is administered in a small but consistent dose helps to preserve therapeutic efficacy while reducing the possibility of adverse effects. Consistent dosage promotes patient compliance and keeps the medicine within its ideal therapeutic window.

- **Drugs having biological half-lives ranging from 2 to 8 hours are ideal for controlled-release formulations.**

A drug's half-life defines how long it is active in the body. Medications with this half-life are useful for regulated drug delivery systems because they allow for continuous release, which reduces the frequency of dosing while maintaining effective drug levels in the blood.

- **When taken orally, the drug's time to reach peak concentration (Tmax) may vary significantly or reach high levels**.

Tmax refers to the time it takes for a drug to reach its maximum concentration in the blood following administration. Variability in Tmax can influence drug efficacy, absorption rate, and the need for controlled-release formulations to ensure steady therapeutic levels.

- **For oral administration, the drug should be absorbed passively, provided its molecular weight does not exceed 1000 Daltons**.

Passive absorption occurs when the drug diffuses across biological membranes without the need for energy or active transport mechanisms. A molecular weight of less than 1000 Daltons is optimal for effective passive absorption, ensuring that the drug can efficiently cross mucosal barriers and reach systemic circulation. [22]

- **The medication should have hydrophilic and lipophilic characteristics.**

A balance of water solubility (hydrophilicity) and fat solubility (lipophilicity) is required for effective medication absorption. Hydrophilic qualities assist the medicine dissolve in bodily fluids, whereas lipophilic features allow it to pass through lipid-rich cell membranes, resulting in increased bioavailability.

- **The composition should be effective without irritating the oral mucosa.**

To guarantee patient comfort and compliance, the medicine should not cause irritation, discomfort, or unpleasant reactions when it comes into touch with the oral cavity's sensitive tissues. A well-tolerated formulation increases long-term therapy adherence while decreasing the risk of inflammation or mucosal injury. [23]

4.2 Bio-adhesive polymer: The first step in creating oral formulations is determining which bio-adhesive polymers are appropriate for the design. Polymeric drug systems play a significant role in Buccoadhesive drug delivery. Additionally, Matrix uses polymer devices, where the drug is encapsulated in a matrix of polymers that controls how long it takes for the drug to release. These polymers are different class of polymers, and enhance patient care and treatment. The drug uses a primary or rate-controlling layer stratum to penetrate into the mucosal surface. Oral drug administration is significantly improved by adhesive polymers. [24]

5. CLASSIFICATION OF ORAL DOSAGE FORMS

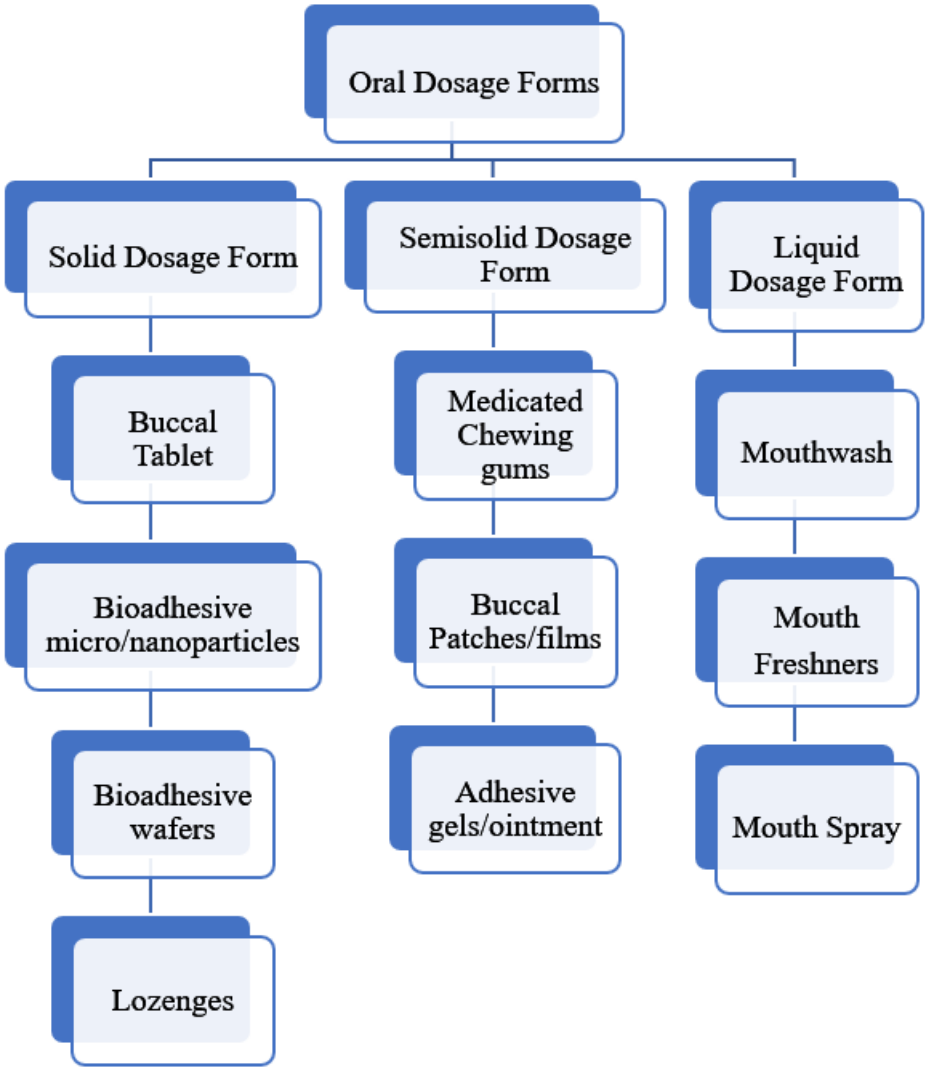

Fig 3. Types of Oral Dosage Forms [12,25]

5.1 Buccal Tablets

Mucoadhesive tablets are tiny, flat, and often spherical, with a thickness of 5 to 8 mm. Unlike normal tablets, these formulations are intended to stick to the mucosal surface, allowing for longer drug retention and controlled release. When administered, they soften and firmly adhere to the mucosa, ensuring continued medication absorption until full dissolution. The mucoadhesive property of these tablets increases medication bioavailability by increasing contact time with the mucus membrane, resulting in higher absorption rates. Furthermore, these tablets provide various benefits, including convenience of administration, the capacity to avoid first-pass metabolism, and increased patient comfort. Their formulation allows patients to chew and speak without irritation, foul taste, or discomfort, making them an extremely effective and patient-friendly drug delivery device. [25]

5.2 Bioadhesive microparticles/nanoparticles

They are advanced delivery systems designed to increase drug retention, absorption, therapeutic efficacy by adhering to biological surfaces such as mucosal tissues. These systems utilize mucoadhesive polymers that interact with mucosal glycoproteins, ensuring prolonged contact time and controlled drug release. Bioadhesive microparticles, ranging from 1 to 1000 µm in size, offer high drug loading capacity and sustained drug release, making them ideal for oral, gastrointestinal, and vaginal drug delivery. Their ability to adhere to mucosal surfaces ensures prolonged local action, reducing the need for regular dosage and improving patient compliance. On other hand, bioadhesive nanoparticles, typically sized between 1 and 1000 nm, provide enhanced cellular penetration, making them suitable for targeted drug delivery, particularly in cancer therapy, ocular drug delivery, pulmonary treatments, and brain-targeted intranasal drug administration. Their small size and high surface area enable efficient drug absorption, controlled release, and reduced systemic toxicity. [26]

5.3 Bioadhesive wafers

They are thin, polymer-based drug delivery systems designed to adhere to biological tissues, particularly mucosal surfaces, for localized and sustained drug release. These wafers utilize mucoadhesive polymers that interact with biological membranes, ensuring prolonged drug retention at application site. Conventional drug delivery methods, such as oral tablets or injections, often suffer from issues like poor bioavailability, rapid drug clearance, and systemic side effects. Bioadhesive wafers address these limitations by enhancing drug absorption, reducing dosing frequency, and providing targeted therapy. They have gained significant attention in buccal, sublingual, vaginal, rectal, and wound-healing applications due to their ease of use and improved therapeutic outcomes. [27]

5.4 Lozenges

Bioadhesive lozenges represent a promising alternative drug delivery system, particularly for medications aimed at the oral cavity and mucosal surfaces. These lozenges are designed to enhance patient compliance and provide sustained drug release, making them suitable for various therapeutic applications. Lozenges work by adhering to the mucosal surfaces of the oral cavity, allowing for prolonged retention and localized drug delivery. This mechanism significantly increases the bioavailability of drugs while reducing gastric irritation and bypassing first-pass metabolism, which is a common issue with conventional oral medications. The extended retention time in the mouth enables a more consistent release of active ingredients, which can include antimicrobials, antifungals, local anaesthetics, and antibiotics. [7,28]

5.5 Medicated chewing gums (MCGs)

MCGs are innovative oral drug delivery systems designed to provide localized and systemic drug effects through chewing action. Unlike conventional dosage forms, MCGs enable prolonged drug release, improved bioavailability, and enhanced patient compliance. These formulations incorporate active pharmaceutical ingredients (APIs) into a chewable gum base, allowing for absorption through the buccal mucosa and the gastrointestinal (GI) tract. MCGs are particularly advantageous for drugs that require fast onset of action, such as nicotine replacement therapy (NRT), pain relief, and motion sickness treatments. They bypass first-pass metabolism, leading to higher bioavailability and reduced gastrointestinal side effects. Additionally, they offer convenience and ease of administration, making them ideal for pediatric and geriatric patients. The development of sugar-free, controlled-release, and functional chewing gums has further expanded their applications in healthcare. With advancements in mucoadhesive polymers, nanotechnology, and flavor-masking techniques, medicated chewing gums continue to evolve as an effective and patient-friendly drug delivery platform for a wide range of therapeutic applications. [29]

5.6 Patches

Several patch systems for administering drugs to the oral mucosa have been developed. There are three types of buccoadhesive patches those with a dissolvable matrix that transfer medications to the oral cavity. Patches are more effective than tablets and lozenges for treating oral yeast infections and mucous membrane inflammation due to their extended drug release. [30,31,]

5.7 Films

Mucoadhesive films provide a more comfortable alternative to adhesive tablets, enhancing patient compliance and ease of use. Unlike oral gels, which are rapidly diluted and removed by saliva, mucoadhesive films ensure prolonged contact with the mucosal surface, leading to more effective drug absorption. These polymer-based film strips dissolve within 30 seconds on the tongue, allowing for rapid drug release and direct entry into the bloodstream. This fast-acting delivery system is particularly beneficial for treating conditions such as erectile dysfunction, headaches, motion sickness, pain relief, and nausea, offering a convenient and efficient alternative to traditional oral medications. [31,32]

5.8 Adhesive Gels/Ointment [31,33]

Based on Origin	Aqueous solubility	Based on Charge	Adhesive force
Polymers that are natural or semi-natural Examples: sodium alginate, chitosan, tragacanth, xanthun gum, gellan gum, agarose, pectin, and carragenan. Cellulose derivatives such as carboxymethyl cellulose, thiolated CMC, sodium CMC, hydroxypropyl methylcellulose, hydroxypropyl cellulose, and methyl hydroxyethyl cellulose, Polyacrylic acid (PAA) include polycarbophil (PC), poly (methyl vinyl ether-co-ethyl hexyl acrylates), polyoxyethylene, polyvinylpyrrolidone (PVP), polyvinyl alcohol (PVA), and thiolated polymers.	Water-soluble polymers Example: HPC, HPMC, and HEC Water-insoluble polymers Examples include PVA, carbopol, and chitosan.	Cations charge Examples: dimethyl aminoethyl-dextran, amino dextran, and trimethylated chitosan Anionic charge Examples: Sodium alginate, chitosan, ethylenediaminetetraacetic acid (EDTA), carbopol (CP), carboxymethyl cellulose (CMC), pectin, polycarbophil (PC), and xanthan gum	Polymers with covalent bonds Examples include PVA, PVP, HPC, and hydroxyethyl starch. The hydrogen bond Examples: CP, PC, PVA, poly (methacrylic acid), and acrylates Interactions between electrons. Example: chitosan

Semi-solid dosage forms such as gels, ointments, and pastes play an important role in oral drug administration because of their ability to stick to the mucosal layer. These formulations are often hydrophobic, forming a protective barrier that improves medication retention and absorption. Bioadhesive gels and ointments are commonly used to heal oral wounds. Orabase, a first-generation bioadhesive paste, is still one of the most widely used therapies for mouth ulcers. It functions as a protective barrier, sheltering ulcers from saliva, limiting drug dilution, and increasing drug penetration to promote quicker healing. Orabase is a formulation composed of finely ground gelatin, pectin and NaCMC, which are suspended in mineral oil and polyethylene gel base. This combination creates a protective and adhesive layer that helps in the prolonged retention of drugs on mucosal surfaces. Additionally, various polymers, including NaCMC, carbopol, hyaluronic acid, and xanthan gum, undergo a phase transition from liquid to semisolid upon application. This transformation increases viscosity, enhancing adhesion to the mucosa and ensuring a controlled and sustained drug release. Such advancements in bioadhesive semi-solid formulations play a crucial role in improving patient compliance by minimizing discomfort and optimizing therapeutic outcomes in oral drug delivery systems.

5.9 Sprays

Spray can carry large molecules, like insulin, over the mouth mucosa. Glyceryl trinitrate is can be swiftly sprayed into the oral mucosa to treat angina. They offer a fast onset of action, making them ideal for conditions that require immediate relief, such as pain management, sore throat treatment, nicotine replacement therapy, and breath freshening. [34]

5.10 Medicated mouthwash

These are specialized oral liquid formulations designed to deliver drugs for the prevention and treatment of various oral conditions such as gingivitis, periodontitis, dental caries, and oral infections. Unlike conventional mouth rinses that are primarily used for freshening breath, medicated mouthwashes contain active pharmaceutical ingredients that provide antiseptic, anti-inflammatory, analgesic, or antifungal effects. These formulations work by reducing bacterial load, soothing inflammation, promoting healing, and delivering localized drug therapy directly to the affected oral tissues. [35]

6. APPLICATIONS OF ORAL MUCOADHESIVE DOSAGE FORMS [24,36]

- **Systemic drug delivery** – It enable direct medication absorption into the systemic circulation, bypassing first-pass metabolism.

- **Local drug delivery** - It is effective in treating oral infections, inflammation, and ulcers because it ensures longer retention at the site of action.

- **Harmone replacement therapy** – It provide a simple, non-invasive option to hormone replacement therapy.

- **Emergency drug delivery** - Buccal formulations allow for quick medication absorption, making them ideal for emergency treatments that require urgent action.

- **Smoking cessation therapy** – These delivery systems are a viable alternative to traditional smoking cessation methods, ensuring longer drug action, improved efficacy, and increased patient adherence in the fight against nicotine addiction.

7. CLASSIFICATION OF POLYEMRS

Table No.1: Types of Polymers [37,38]

7.1 NEW GENERATION POLYMERS

New-generation polymers can create covalent connections with mucus and underlying cell layers, resulting in more efficient chemical interactions. Unlike thiolated polymers, new-generation mucoadhesives can stick directly to the cell surface using particular receptors or covalent bonding, as opposed to the non-specific methods used in prior generations.

7.1.1 Lectins- Lectins are a broad class of carbohydrate-binding proteins found in plants, mammals, fungi, and microbes. They recognize and bind to sugar molecules (glycans) on cell surfaces, playing an important role in a variety of biological processes such as cell-cell communication, immunological responses, and pathogen detection. Unlike enzymes, lectins do not change the sugars they bind to; instead, they enable interactions between cells and biomolecules. They have been studied for targeted drug delivery because of their capacity to attach to specific sugar structures on mucosal surfaces, hence increasing medication absorption and bioavailability. [38]

Polyox Water Soluble Resins- It commonly known as polyethylene oxide (PEO) polymers, are a class of high-molecular-weight hydrophilic polymers that are widely employed in medicinal, cosmetic, and industrial settings. These resins are well-known for their water solubility, mucoadhesive capabilities, film-forming ability, and controlled drug release features, making them an essential component in modern drug delivery systems. This resins quickly dissolve in water, resulting in very viscous solutions that promote medication retention and bioavailability. Their compatibility with biological surfaces, particularly mucosal tissues, makes them ideal for mucoadhesive drug delivery systems, transdermal patches, and controlled-release formulations. [39]

7.1.2 Thiolated Polymers- These polymers, commonly known as thiomers, are a type of bioadhesive polymer that has been chemically modified to include thiol (-SH) groups. These polymers have better mucoadhesive characteristics, improved drug retention, and controlled drug release, making them extremely efficient in mucoadhesive drug delivery systems. The presence of thiol groups allows them to establish disulfide bonds with cysteine-rich domains of mucins, considerably boosting their adhesion strength and prolonging drug contact duration on mucosal surfaces. [40,41]

7.1.3 Novel Polymers

Tomato lectin, a plant-derived carbohydrate-binding protein, has been intensively explored for its ability to bind specifically to the small intestine epithelium, making it a prospective candidate for targeted medication delivery and bioadhesion. Because of its strong affinity for intestinal glycoproteins, tomato lectin increases medication residence time on the intestinal mucosa, enhancing absorption and bioavailability. This characteristic is especially useful in oral drug delivery systems, where site-specific adhesion and regulated drug release are essential for therapeutic efficacy. Along with this, Corium Technologies has created hydrophilic pressure-sensitive adhesives (PSAs) with improved bioadhesion and flexibility for drug delivery applications. These PSAs are created through hydrogen-bonded, non-covalent crosslinking mechanisms between a hydrophilic polymer and a plasticizer with reactive hydroxyl groups. The non-covalent hydrogen bonding between these components forms a highly flexible, biocompatible, and moisture-responsive adhesive matrix that may adhere to biological tissues without causing irritation or discomfort. [8,42]

8. EVALUATION OF BUCCAL MUCOADHESIVE DOSAGE FORMS

8.1 Drug-excipient interaction studies

These studies are essential in the formulation of solid dosage forms to ensure stability, compatibility, also efficacy of the final formulation. Various analytical techniques, including DSC, XRD, FTIR, are commonly employed to detect potential interactions between the drug and excipients. DSC is particularly useful in identifying incompatibilities by analyzing changes in melting endotherms, exotherms, reaction enthalpies, and overall thermal behaviour. Shifts in melting points or the appearance of new thermal events may indicate interactions such as complex formation or degradation. These studies are crucial for optimizing formulations, ensuring drug stability, and preventing potential adverse effects caused by incompatibilities between drug and excipient components. Physical evaluation. [43,44]

- **Weight uniformity test** - Weight is measured weight variance by comparing the average weight of selected patches to individual patches of sample. [45]

- **Thickness test**- Measure film thickness at five points to find the average thickness. Samples with tears, air bubbles, and a mean thickness variation of more than 5% are excluded from analysis. [46]

- **Folding endurance-**It is patches tested by folding patches repeatedly until they broke or manually folding them up to 300 times, indicating good patch qualities. Folding endurance is determined by the number of folds the patch can withstand without breaking. This test is conducted on five patches. [46,47]

8.2 Determination of surface pH

The formulation is allowed to equilibrate with a few drops of distilled water or phosphate buffer (pH 6.5-7.0) for about 1-2 hours at room temperature.[48] This hydration process ensures that any soluble surface components dissolve into the medium, resulting in an accurate pH value. A pH-sensitive electrode or a digital pH meter is then carefully put on the moistened surface, and the reading is taken after one minute of stabilization. Multiple readings may be collected at various stages of the formulation to verify consistency and reproducibility of results. [49]

8.3 Swelling studies

A 1x1 cm2 drug-loaded patch was placed in 50 ml of phosphate buffer (pH 6.8). After five minutes, at specific time intervals, the sample is removed, blotted to remove excess liquid, and weighed again. [50]

$$\text{Swelling Index (\%)} = (\text{Final Weight} - \text{Initial Weight}) / (\text{Initial Weight}) \times 100$$

8.4 Determination of mechanical properties

- **Tensile strength** – It is measured by calculating the force required to break the bioadhesive bond between mucus membrane and the polymer. To determine the tensile strength of a buccal mucoadhesive device, use the following formula.

$$\text{Force of adhesion} = \text{mucoadhesive strength} \times 9.81/1000.$$

$$\text{Bond strength (N/m2)} = \text{force of adhesion (N)/surface area of tablet (m2).}$$

The instruments used to determine the tensile strength are Modified physical balance or tensile tester and Wilhelmy plate technique. [51]

- **Shear strength** – in this technique, select two smooth polished glass boxes and attach one to a glass plate using glue on a leveled surface. Tie a thread to the higher block and use a pulley to move it down. The thread length from the pulley should be 12 cm. Attach a 17g pan and weights to the bottom of the thread. The shear strength was estimated by calculating the weight required to break the adhesion. [52]

8.5 The fluorescent probe method

This approach involves labeling the lipid bilayer of cultivated human conjunctiva cells with pyrine and using it as a fluorescent probe. Adherence of the polymer to the cell can result in a shift in fluorescence due to surface compression, as compared to control cells. The degree of fluorescence is directly proportional to polymer binding. Another probe can be used to measure density of adhesion, polymer charge, and charge sign. The bioadhesive bond is determined by the polymer's interaction with mucus molecules. [53]

8.6 Mucoadhesive strength

To determine ex-vivo mucoadhesive strength, a modified balance method is used. Fresh mucosa buccal of goat or sheep, collected and consumed within 2 hours of slaughter. The mucosal membrane was washed at 37°C with distilled water, followed by a phosphate buffer (pH 6.8). The oral mucosa was sliced into minute pieces and rinsed with a phosphate buffer at pH 6.8. A portion of buccal mucosa was affixed to a glass vial filled with phosphate buffer. Before the investigation, the modified balance's two sides were balanced by placing a 5 g weight on the right side of the pan. 5 g weight was removed from the right side of the pan, which was then lowered over the mucosa and pill. The balance remained in this position for 5 minutes. [54] Using an infusion rate of 100 drops per minute on the right side of the pan, water was slowly injected until the pill detached from the mucosal surface. Buccal tablet's mucoadhesive power in grams. At 37 °C ± 1 °C, the glass vial was tightly placed into a glass beaker filled with a phosphate buffer (pH 6.8), barely reaching the mucosal surface. [55]

8.7 Mucoadhesion residence time

To determine ex-vivo mucoadhesion time was measured on newly cut buccal mucosa after applying a goat or sheep buccal patch. The fresh buccal mucosa was wrapped on a glass slide, and 1 drop of phosphate buffer (pH 6.8) was applied to the mucoadhesive core side of each tablet. The tablets were then glued to the sheep's buccal mucosa using light force at the tip of the finger for 30 seconds. [56]

8.8 Drug release study

This process is often investigated using a dissolution equipment, such as a Franz diffusion cell, in which the buccal patch comes into contact with a simulated saliva solution or phosphate buffer at physiological pH. [57] The drug's release from the patch is determined by various parameters, including the nature of the polymer matrix, the presence of permeation enhancers, and the drug's solubility. Depending on the formulation design, the drug diffusion mechanism may use zero-order, first-order, or Higuchi kinetics. UV spectrophotometry is used to examine the samples collected at certain time intervals. [58]

8.9 Drug permeation

In-vitro drug permeation of a buccal patch is an important investigation to determine the drug's capacity to permeate past the buccal mucosa or synthetic membrane and into the systemic circulation. This investigation is often conducted using a Franz diffusion cell or a similar equipment in which the buccal patch comes into direct contact with a semi-permeable membrane such as dialysis membrane, porcine buccal mucosa, or cellophane membrane. The receptor compartment is filled with a simulated saliva solution or phosphate buffer (pH 6.8) and kept at 37 ± 0.5°C to replicate physiological circumstances. [59] The membrane serves as a barrier, resembling the buccal mucosal layer through which the medication passes. Samples are removed at regular time intervals and examined using UV spectroscopy to determine drug concentration in the receptor media. The total amount of drug penetrated is plotted against time to determine permeation characteristics such as flux, permeability coefficient, and steady-state permeation rate. [60]

9. CHALLENGES AND FUTURE PERSPECTIVES

Mucoadhesive systems have potential to enhance therapeutic efficacy in several medical applications by overcoming limitations of previous methods. Further research and innovation in polymers, nanotechnology, and formulation design are necessary to overcome limits and optimize performance. Biological adhesive hydrogels with customizable properties offer promising approach for managing drug release and targeting specific regions, enhancing the effectiveness of this system. Additionally, combining mucoadhesive technologies with other advanced techniques, such as nanoparticles or liposomes, can significantly improve therapeutic outcomes by enabling controlled release, increased bioavailability, and targeted delivery. The future of mucoadhesive delivery also includes personalized medicine, where formulations can be tailored based on individual characteristics, including disease status and mucosal properties, to improve treatment effectiveness and reducing adverse reactions. By integrating these

advancements, mucoadhesive drug delivery systems will continue to evolve, offering more efficient, patient-centric, and versatile treatment options.

10. CONCLUSION

Mucoadhesive drug delivery systems have developed as a game-changing concept in pharmaceutical sciences, providing various benefits over traditional drug delivery methods. These systems overcome the limits of standard oral drug administration by deploying bioadhesive polymers that engage with mucosal surfaces, resulting in improved drug retention, controlled release, and increased bioavailability. Mucoadhesive formulations' ability to escape first-pass metabolism and enzymatic degradation makes them especially useful for medicines with low solubility and bioavailability. These formulations not only give localized drug effects but also aid in systemic absorption, making them excellent for treating illnesses that require long-term drug release. Despite their advantages, mucoadhesive drug delivery systems confront a number of hurdles that must be overcome before they can be widely used. Mucosal surface variability, fast mucus turnover, enzymatic activity can have an impact on adhesion and drug release. Furthermore, formulation stability, possible toxicity, and patient compliance are major problems. The development of innovative bioadhesive polymers, such as thiolated polymers and lectin-based systems, is helping to address these issues by enhancing adhesion strength, drug loading capacity, and biocompatibility. Recent advances in polymer technology, nanotechnology, and material science have further transformed mucoadhesive medication delivery. Innovative techniques, such as bioadhesive nanoparticles, hydrophilic pressure-sensitive adhesives, and functionalized mucoadhesive coatings, improve medication delivery precision and patient comfort. Future research should concentrate on optimizing formulation procedures, increasing scalability, and assuring regulatory compliance in order to promote the commercialization of these sophisticated dosage forms. To summarize, this route of delivery are promising and unique technique to drug administration, providing increased therapeutic efficacy, tailored therapy, and improved patient adherence. With ongoing research and technology breakthroughs, these systems have the potential to alter the pharmaceutical landscape by offering safer and more effective treatment choices for a wide range of ailments.

CONSENT AND EHICAL APPROVAL

It is not applicable.

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REFERENCES

1. Sharma M, Sheeba FR, Yadav RP, Patel AK, Kumar Y. Mucoadhesive polymers for buccal drug delivery system: An overview. Asian Journal of Pharmaceutical Research and Development. 2021 Apr 15;9(2):57-64.
2. Asati S, Jain S, Choubey A. Bioadhesive or Mucoadhesive Drug Delivery System: A Potential Alternative to Conventional Therapy. Journal of Drug Delivery and Therapeutics. 2019 Nov 11;9(4-A):858–67.
3. Puri V, Sharma A, Maman P, Rathore N, Singh I. Overview of mucoadhesive biopolymers for buccal drug delivery systems. Int. J. Appl. Pharm. 2019 Oct;11(6):10-22159.
4. Parmar H. K, Pandya K.K, Pardasani L.J, Panchal V.S, Tandel T. A systematic review on mucoadhesive drug delivery system. World J Pharm Res. 2017; 6(9): 337-66.
5. Bagade OM, Mali AR, Survase SS, Chaudhari AK, Doke PE. An updated overview on mucoadhesive buccal drug delivery system. Research Journal of Pharmacy and Technology. 2021;14(8):4495-500.
6. Chauhan V, Agrawal A, Singh UK. A comprehensive review on mucoadhesive drug delivery. Journal of Drug Delivery & Therapeutics. 2022 Jul 2;12(4-S):199-209.
7. Golshani S, Vatanara A, Amin M. Recent advances in oral mucoadhesive drug delivery. Journal of Pharmacy & Pharmaceutical Sciences. 2022 Jun 15;2(5):201-17.
8. Mahajan P, Kaur A, Aggarwal G, Harikumar SL. Mucoadhesive drug delivery system: a review. Int J Drug Dev Res. 2013 Jan;5(1):11-20.
9. Gandhi SD, Pandya PR, Umbarkar R, Tambawala T, Shah MA. Mucoadhesive drug delivery systems-An unusual maneuver for site specific drug delivery system. Int J Pharm Sci. 2011 Jul;2(3):132-52.
10. Patil KH, Mobin SA. Advances in Mucoadhesive drug Delivery System: Enhancing Efficacy and Patient Compliance. Journal of Drug Delivery & Therapeutics. 2024 Oct 1;14(10)
11. Satyabrata B, Ellaiah P, Choudhury R, Murthy KV, Bibhutibhusan P, Kumar MS. Design and evaluation of methotrexate buccal mucoadhesive patches. Int J Pharm Biomed Sci. 2010;1(2):31-6.

12. Aishwarya MN, Raj VP, Debnath S, Babu MN. A review on buccal drug delivery system. Research Journal of Pharmaceutical Dosage Forms and Technology. 2017;9(3):109-13.
13. Singh PK, Singh D, Bijauliya RK. A Comprehensive Review on Buccal Drug Delivery System. International Journal of Research. 2017 Apr;6(3):2606-18.
14. Alexander A, Tripathi DK, Verma T, Maurya J, Patel S. Mechanism responsible for mucoadhesion of mucoadhesive drug delivery system: a review.
15. Madhav NS, Ojha AB, Tyagi YO, Negi MO. Mucoadhesion: a novelistic platform for drug delivery system. Int J Pharm. 2014 Sep 25;2(9):246-58.
16. MISHRA R, VERMA S. An Overview of Buccal Drug Delivery System. International Journal of Pharmaceutical Research (09752366). 2021 Jan 1;13(1).
17. Ahmed TA, Bawazir AO, Alharbi WS, Safo MK. Enhancement of simvastatin ex vivo permeation from mucoadhesive buccal films loaded with dual drug release carriers. International Journal of Nanomedicine. 2020 Jun 9:4001-20.
18. Mamatha Y, Prasanth VV, Kumar SA. Buccal drug delivery a technical approach. Journal of Drug Delivery and Therapeutics. 2012;2(2):26-33.1
19. Boddupalli BM, Mohammed ZN, Nath RA, Banji D. Mucoadhesive drug delivery system: An overview. Journal of advanced pharmaceutical technology & research. 2010 Oct 1;1(4):381-7.
20. Laffleur F. Mucoadhesive polymers for buccal drug delivery. Drug development and industrial pharmacy. 2014 May 1;40(5):591-8.
21. Shaikh R, Singh TR, Garland MJ, Woolfson AD, Donnelly RF. Mucoadhesive drug delivery systems. Journal of pharmacy and Bioallied Sciences. 2011 Jan 1;3(1):89-100.
22. Alawdi S, Solanki AB. Mucoadhesive drug delivery systems: A review of recent developments. Journal of Scientific Research in Medical and Biological Sciences. 2021 Feb 28;2(1):50-64.
23. Parthasarathy G, Bhaskar K, Jayaveera KN, VV P. Buccal mucosa a gifted choice for systemic drug delivery. International Journal of Drug Delivery. 2011 Oct 1;3(4):586.
24. Tangri P., Madhav N.V.S. (2011), Oral Mucoadhesive Drug Delivery System-A Review, Int. J. Of Bio pharm., 2(1):36-46.
25. Gilhotra RM, Ikram M, Srivastava S, Gilhotra N. A clinical perspective on mucoadhesive buccal drug delivery systems. Journal of biomedical research. 2013 Jun 6;28(2):81
26. Hamedi H, Moradi S, Hudson SM, Tonelli AE, King MW. Chitosan based bioadhesives for biomedical applications: A review. Carbohydrate Polymers. 2022 Apr 15;28(2):119-100.
27. Saxena A, Tewari G, Saraf SA. Formulation and evaluation of mucoadhesive buccal patch of acyclovir utilizing inclusion phenomenon. Brazilian Journal of Pharmaceutical Sciences. 2011,47:887-97.
28. Pothu R, Yamsani MR. Lozenges formulation and evaluation: A review. International Journal of Advances in Pharmaceutical Research. 2014 May;5(5):290-8.
29. Chatterjee B, Amalina N, Sengupta P, Mandal UK. Mucoadhesive polymers and their mode of action: A recent update. Journal of Applied Pharmaceutical Science. 2017 May 30;7(5):195-203.
30. Mahadik RA, Redasani VK, Jadhav PD, Bhagat PD. Review on a Oral Mucoadhesive Drug Delivery System. Asian Journal of Pharmaceutical Research and Development. 2023 Jul 3;11(3):201-5.
31. Shipp L, Liu F, Kerai-Varsani L, Okwuosa TC. Buccal films: A review of therapeutic opportunities, formulations & relevant evaluation approaches. Journal of Controlled Release. 2022 Dec 1;35(2):1071-92.
32. Yun G, Choi SU, Park KH, Rhee YS, Lee BJ, Lee JH. Pharmaceutical devices for oral cavity-based local and systemic drug delivery. Journal of Pharmaceutical Investigation. 2010;40(spc):113-8.
33. Keukenmeester RS, Slot DE, Putt MS, Van der Weijden GA. The effect of medicated, sugar-free chewing gum on plaque and clinical parameters of gingival inflammation: a systematic review. International Journal of Dental Hygiene. 2014 Feb;12(1):2-16.
34. Punitha S, Girish Y. Polymers in mucoadhesive buccal drug delivery system: A review. Int J Res Pharm Sci. 2010;1170–86
35. Sheoran R. Buccal drug delivery system: A review. Int J Pharm Sci Rev Res. 2018 May;50(1):40-6.
36. Dekina S, Romanovska I, Ovsepyan A, Tkach V, Muratov E. Gelatin/carboxymethyl cellulose mucoadhesive films with lysozyme: Development and characterization. Carbohydrate polymers. 2016 Aug 20;14(7):208-15.
37. Thakur B, Pandit V, Ashawat MS, Kumar P. Natural and synthetic polymers for colon targeted drug delivery. Asian Journal of Pharmaceutical Research. 2016;6(1):35-44.
38. Andrews GP, Laverty TP, Jones DS. Mucoadhesive polymeric platforms for controlled drug delivery. European journal of pharmaceutics and biopharmaceutics. 2009 Mar 1;71(3):505-18.
39. Pandey GS, Pandey AN. Critical review on buccal mucoadhesive drug delivery systems. International Journal of Health Sciences. 2022(II):431211.
40. Lehr CM. Lectin-mediated drug delivery:The second generation of bioadhesives. Journal of Controlled Release. 2000 Mar 1;65(1-2):19-29.
41. Puri V, Sharma A, Maman P, Rathore N, Singh I. Overview of mucoadhesive biopolymers for buccal drug delivery systems. Int. J. Appl. Pharm. 2019 Oct;11(6):10-22159.

42. Verma S. Polymers in designing the mucoadhesive films: A comprehensive review. International Journal of Green Pharmacy (IJGP). 2018 Aug 3;12(02).
43. Jasti B, Li X, Cleary G. Recent advances in mucoadhesive drug delivery systems. Pharma Tech. 2003;1(9)4:6.
44. Saatkamp RH, Dos Santos BM, Sanches MP, Conte J, Rauber GS, Caon T, Parize AL. Drug-excipient compatibility studies in formulation development: A case study with benznidazole and monoglycerides. Journal of Pharmaceutical and Biomedical Analysis. 2023 Oct 25;23(5):115634.
45.Khairnar GA, Sayyad FJ. Development of buccal drug delivery system based on mucoadhesive polymers. Int J PharmTech Res. 2010;2(1):719-35.
46.Shirvan AR, Bashari A, Hemmatinejad N. New insight into the fabrication of smart mucoadhesive buccal patches as a novel controlled-drug delivery system. European Polymer Journal. 2019 Oct 1;11(9):541-50.
47. Peppas NA, Buri PA. Surface, interfacial and molecular aspects of polymer bioadhesion on soft tissues. Journal of Controlled Release. 1985 Nov 1;2,257-75.
48. Singh R, Sharma D, Garg R. Review on mucoadhesive drug delivery system with special emphasis on buccal route: an important tool in designing of novel controlled drug delivery system for the effective delivery of pharmaceuticals. J Dev Drugs. 2017 Mar 20;6(01):1-2.
49. Patel VM, Prajapati BG, Patel MM. Design and in vitro characterization of eudragit containing mucoadhesive buccal patches. International Journal of PharmTech Research. 2009;1(3):783-9.
50. Salehi S, Boddohi S. New formulation and approach for mucoadhesive buccal film of rizatriptan benzoate. Progress in biomaterials. 2017 Dec;6,175-87.
51. Yamsani MR, Kishan V, Yasmani MR. Development of mucoadhesive patches for buccal administration of prochlorperazine: evaluation of in vitro release and mechanical properties. Int. Phar Sci and Nanotech. 2008;1,64-70.
52. Manivannan R, Balasubramaniam A, Anand DC, Sandeep G, Rajkumar N. Formulation and in-vitro evaluation of mucoadhesive buccal tablets of diltiazem hydrochloride. Research Journal of Pharmacy and Technology. 2008;1(4):478-80.
53. Parmar HK, Pandya KK, Pardasani LJ, Panchal VS, Tandel T. A systematic review on mucoadhesive drug delivery system. World J Pharm Res. 2017 Jun 30;6(9):337-66.
54. Khairnar A, Jain P, Baviskar D, Jain D. Development of mucoadhesive buccal patch containing aceclofenac: in vitro evalu ations. Int J PharmTech Res. 2009 Oct;1(4):978-81.
55. Koirala S, Nepal P, Ghimire G, Basnet R, Rawat I, Dahal A, Pandey J, Parajuli-Baral K. Formulation and evaluation of mucoadhesive buccal tablets of aceclofenac. Heliyon. 2021 Mar 1;7(3).
56. Singh R, Sharma D, Garg R. Review on mucoadhesive drug delivery system with special emphasis on buccal route: an important tool in designing of novel controlled drug delivery system for the effective delivery of pharmaceuticals. J Dev Drugs. 2017 Mar 20;6(01):1-2.
57. Rhushikesh S, Suresh S. A Review on Mucoadhesive Drug Delivery System. Int. J. Res. Anal. Rev. 2020;7(1):793-808.
58. Sudhakar Y, Kuotsu K, Bandyopadhyay AK. Buccal bioadhesive drug delivery—a promising option for orally less efficient drugs. Journal of controlled release. 2006 Aug 10;114(1):15-40.
59. Parmar HG, Jain JJ, Patel TK, Patel VM. Buccal patch: A technical note. Int J Pharm Sci Rev Res. 2010;4(3):2010.
60. Patel R, Naik S, Patel J, Baria A. Formulation development and evaluation of mouth melting film of ondansetron. Arch Pharm Sci Res. 2009 Oct;1(2):212-17

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