



Overall Review: On Mucosal Drug Delivery System

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Abstract

The research on mucosal drug delivery systems is systematically reviewed in this study, which also looks at the systems' potential for drug administration in the future. MDDS have drawn a lot of interest lately due to their ability to increase medication absorption, boost therapeutic efficacy, and reduce adverse systemic effects. The material currently available on MDDS, including several mucosal routes such oral, nasal, ocular, pulmonary, and vaginal delivery, is critically assessed in this review.

The benefits, difficulties, and most recent developments in mucosal drug administration are examined in this study, with an emphasis on systemic and local therapeutic uses. Mucosal administration is a desirable alternative for medications with poor gastrointestinal absorption or breakdown by digestive enzymes due to its quick onset of action and avoidance of first-pass metabolism. All things considered, this systematic review presents insightful information about the state of MDDS today as well as suggestions for further study and advancement in this area.

Keywords: mucoadhesion, bioadhesion, transmucosal, mucosal layer, permeability.

Introduction:

The oral route is the most widely used way to administer drugs, where the medication is ingested and mostly passes past the small intestine's barrier to enter the systemic circulation. The most crucial technique for delivering medications for systemic effects is the oral route. Parenteral administration is not frequently utilized for self-administration of medicine. It is likely that oral administration accounts for at least 90% of all medications used to elicit systemic effects.

Early in the 1980s, the field of controlled release medication delivery devices developed the idea of mucoadhesion. Subsequently, a number of studies concentrated on examining the interfacial interactions between mucus and mucoadhesive hydrogels. The word "bioadhesion" refers to the attachment of a drug carrier system to a particular biological site for drug delivery purposes. Epithelial tissue may be the biological surface. A delivery mechanism that sticks to the mucous membrane is maintained via mucoadhesion. The following are the mucosal routes of drug delivery,

1. Buccal route.
2. The ophthalmic/ocular route.
3. The vaginal route.
4. The nasal route.
5. Topical Route.

Advantages of mucoadhesive drug delivery systems

1. Drugs boost bioavailability by avoiding first-pass metabolism.
2. In an emergency, drugs are simple to administer.
3. Some medications can be given by buccal delivery since they are unstable in the stomach's acidic environment.
4. Extended periods of drug release
5. The medication is absorbed through passive diffusion in this system.
6. Flexibility in terms of surface, size, shape, and real condition.

Disadvantages of mucoadhesive drug delivery systems

1. It is not possible to deliver medications that are unstable at buccal PH.
2. This method cannot be used to provide medications that have a pleasant or bitter taste or that cause irritation to the mucosa.
3. Drugs that are required in modest amounts need to be managed.
4. Those drugs that inactive patients take.

1. Anatomy of the oral mucosa

The oral mucosa, which lines the inside of the mouth, is a complex structure that serves immunological, sensory, and defensive purposes. It is made up of multiple layers and parts.

1.1. Epithelium:

which is composed of the following four layers, covers the oral mucosa and shields the cells from harm.

- | | |
|--|--------------------------|
| i. The basal layer, or stratum. | iii. Granulosum stratum. |
| ii. The prickle-cell layer, or stratum spinosum. | iv. Corneum stratum. |

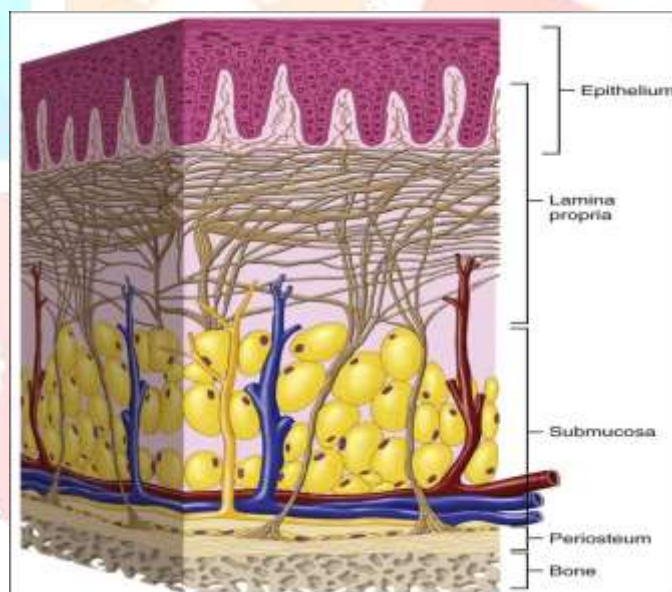


Fig 1: Structure of oral mucosa

1.2. Lamina Propria:

Made of connective tissue, the lamina propria lies beneath the epithelium and supports and nourishes the latter.

1.3. Submucosa:

This deeper layer, which gives some areas of the oral cavity flexibility and mobility, is called the submucosa. It has blood arteries, nerves, fatty tissues, loose connective tissue, and small salivary glands.

1.4. Specialized Mucosa:

The taste buds are housed in a specialized mucosa with lingual papillae on the dorsal aspect of the tongue.

2. The Routes of Mucosal drug delivery :

For targeted and regulated release delivery to many organelles based on mucosal membranes, mucoadhesive formulations have been employed extensively. While avoiding bioavailability-limiting effects such hepatic or enzymatic degradation, such formulations may supply active ingredients for local or systemic effects.

2.1. Buccal drug delivery

There are numerous benefits to using the buccal cavity for medication delivery. Low enzymatic activity and great accessibility are the two main benefits. Additionally, by removing the dose form, buccal medication distribution can be quickly stopped in cases of toxicity, providing a simple and safe way to use the drug¹⁹. The transport of peptides, proteins, and polysaccharides through a variety of polymers, including sodium carboxymethylcellulose, hydroxypropyl cellulose, and polycarbophil, has been studied. The most practical forms are gels and ointments, but tablets, patches, and films have all been studied. Additionally, buccal drug delivery has been linked to low levels of discomfort, high patient compliance, and notable simplicity of administration.

2.1.1. Buccal mucosal structure

The outermost layer of stratified squamous epithelium makes up the oral mucosa. A basement membrane and a lamina propria are located beneath this, followed by the Figure shows the submucosa as the deepest layer. The sublingual epithelium has slightly fewer cell layers than the buccal mucosa's, which has between 40 and 50 cell layers. As the epithelial cells move from the basal layers to the superficial layers, they get bigger and flatter. It has been estimated that the buccal epithelium has a turnover time of 5–6 days²⁰, which is most likely typical of the oral mucosa overall. Depending on the location, the thickness of the oral mucosa varies: the buccal mucosa is 500–800 μm thick,

Composition of oral mucosa

Water.....	95%
Glycoproteins and lipids.....	0.5-5%
Mineral salts.....	1%
Free proteins.....	0.5-1%

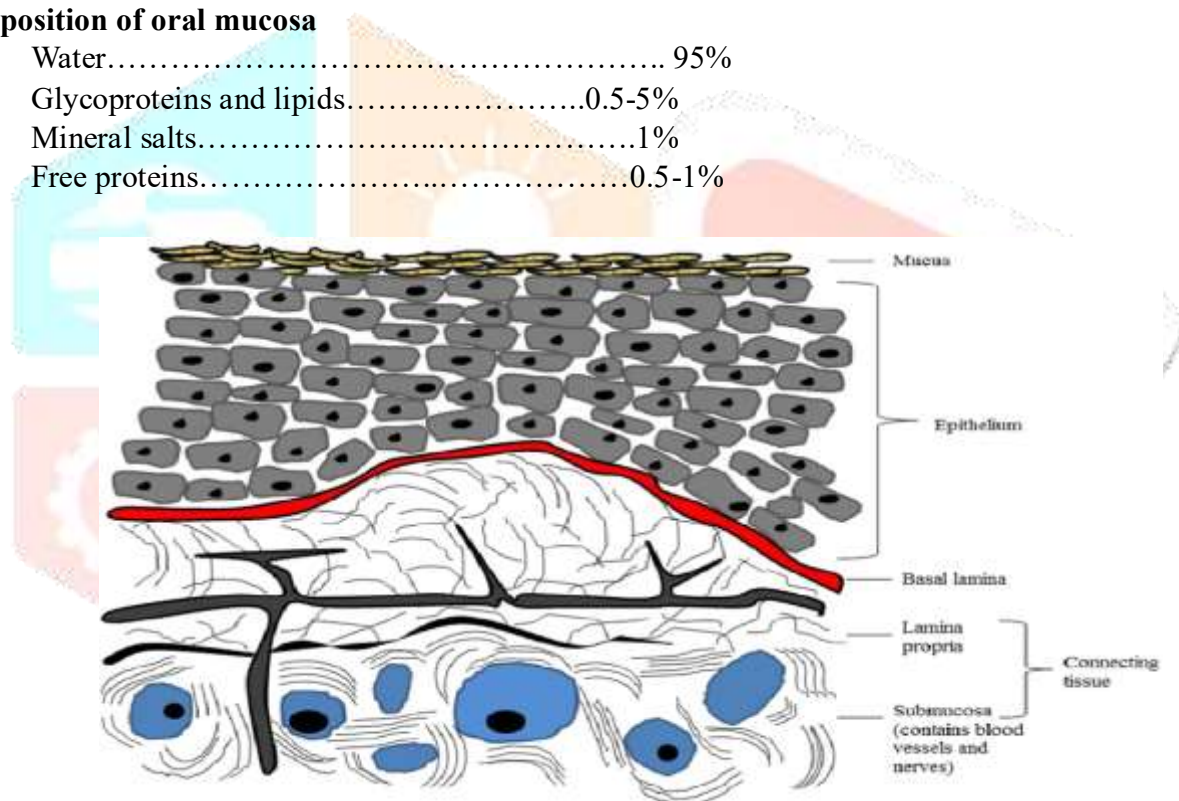


Fig.2. Structure of buccal mucosa

2.1.2. FACTORS AFFECTING THE BUCCAL DRUG DELIVERY SYSTEM

1. Permeability

The buccal mucosa's permeability is thought to be 4–4000 times higher than the skin's, and because different oral mucosae have varied forms and functions, the permeability varies between the various oral cavity regions.

Concentration of active polymer

The adhesive strength diminishes as the polymer concentration rises.

2. PH

The charge on the surface of polymers and mucus is influenced by PH. Because of variations in the dissociation of functional groups on the carbohydrate moiety and amino acids of the polypeptide backbone, mucus will have a varied charge density based on pH. For instance, polycarbophil had its strongest adhesive strength at pH 3, which progressively diminished as the pH rose to 5. Beyond pH 5, polycarbophil exhibited no mucoadhesive characteristics.

3. Hydrogen bonding

It is also a significant element that may influence mucoadhesion. Park and Robinson discovered that functional groups capable of forming hydrogen bonds must be present in desired polymers for mucoadhesion to occur.

4. Hydration

In addition to causing mobility in the polymer chains to improve the interpenetration process between the polymer and mucin, hydration is necessary for a mucoadhesive polymer to expand and form an appropriate "macromolecular mesh" of enough size.

5. Salivary Enzymatic Degradation:

Salivary enzymes can break down medications before they are absorbed through the mucosa, especially peptides and proteins that are susceptible to enzymatic breakdown, which decreases the medications potency.

2.1.3. ADVANTAGES OF BUCCAL DRUG DELIVERY SYSTEM

- This suggests a quick start to action.
- The buccoadhesive method can be used to give medications that are unstable when taken orally or gastrically.
- Extended periods of drug release
- Patients who are traumatized or unconscious may receive medication.
- By avoiding the first-pass metabolism, medications have a higher bioavailability.
- Buccal administration is an option for medications that are unstable in the stomach's acidic environment.
- The passive diffusion method of drug absorption.
- Physical state, shape, size, and surface flexibility.

2.2. Ophthalmic drug delivery

A variety of dosage forms, such as liquid drops, gels, ointments, and solid ocular inserts (both biodegradable and nonbiodegradable), can be used to deliver therapeutic substances to the eye. An in situ gelling polymer that undergoes a phase shift following application is another intriguing delivery method. In vivo, mucoadhesive polymers should exclusively adhere to conjunctival mucus. Furthermore, because carbomer and polycarbophil have a high propensity for swelling in the neutral pH environment of the eye, restricted bioavailability has been noted in vivo for these polymers. It is unacceptable to maintain a low viscosity in such systems by pH regulation in the range of 4-5 because this could cause minor lacrimation and pain for the patient, both of which would affect the effectiveness of treatment. Such dose forms may therefore be subject to psychological and physical hurdles that impede user acceptance and compliance.

2.3. Vaginal drug delivery systems

There are numerous benefits of vaginal drug delivery, such as avoiding hepatic firstpass metabolism, reducing hepatic adverse effects, and avoiding discomfort, tissue damage, and infection that are frequently seen with parenteral drug delivery routes of administration. The vagina's huge surface area, abundant blood supply, high permeability, and low retention because of the vaginal tract's self-cleaning action—which is frequently problematic—make it a suitable target for systemic drug delivery. The vaginal membrane's change during the menstrual cycle and post-menopausal period is another crucial factor to take into account. Typical bio-adhesive polymers that have been used in vaginal formulations include polycarbophil and hydroxypropyl cellulose. However, residence times within the vagina tend to be much higher than those at other absorption sites like the rectum or intestinal mucosa.

2.3.1. ADVANTAGES OF VAGINAL DRUG DELIVERY SYSTEM:

Compared to traditional dose forms, mucoadhesive vaginal delivery systems offer a number of benefits.

1. Because of the strong blood supply provided by the arteries and veins in the vagina, drugs administered through this route have a good absorption rate and prevent the first-pass effect.
2. It also prevents the gastrointestinal tract from interfering with medicine absorption.
3. As a result, the drug's bioavailability rose.
4. Administering drugs vaginally reduces the negative consequences of taking them orally.

5. In bioadhesive vaginal formulations, it exhibits high bioavailability for progesterone, estrogen, calcitonin, and insulin.

6. It lessens adverse effects by avoiding repetitive drug administration.

2.4. Nasal drug delivery

One of the main benefits of intranasal medication delivery is that, because blood is emptied straight from the nose into the systemic circulation, the nasal cavity offers a sizable, highly vascularized surface area that allows first-pass metabolism to be avoided. Microparticles, gels, liquids, and powders have all been used to successfully deliver medications through the nose. For the quick alleviation of nasal congestion, solutions containing sympathomimetic vasoconstrictors are the most often used intranasal active ingredients.

Local delivery of these alpha-adrenergic stimulators is of particular benefit to patients with high blood pressure (or those at heightened risk of cardiovascular incidents), as vasoconstriction will occur to the greatest degree within the nose. In addition to local effects, the intranasal route of drug administration has been used to achieve a distal systemic effect. One such example is the intranasal delivery of the peptide desmopressin that exerts its action on the kidneys, mimicking the action of antidiuretic hormone, used mainly in Diabetes insipidus

TABLE I. Advantages of nasal drug delivery

Aspect	Systemic Nasal Delivery	Local Nasal Delivery
Aim	Delivering drugs into the bloodstream for systemic therapeutic effects..	Treating conditions directly in the nasal or upper respiratory tract.
Onset of Action	Rapid, due to rich vascular network in the nasal mucosa.	Fast, providing immediate relief of local symptoms.
Bioavailability	High for many drugs, especially those that avoid first-pass metabolism.	Localized action, minimizing systemic absorption.
First-Pass Metabolism	Avoided, leading to higher bioavailability.	Not relevant for local delivery.
Side Effects	often reduced compared to oral delivery.	Minimal systemic side effects due to localized drug action.

TABLE II. Different types of mucoadhesive dosage forms

Delivery routes	Dosage forms			
	Tablet	Ointment	Gel	Patch
Buccal	Theophylline, multiple polymers	Benzyl nicotinate, multiple polymers	Benzylamine, chitosan derivatives	Miconazole, PVA/PVP F
Nasal	N/A	Mupirocin, glycerin ester	Insulin, starch	Insulin, chitosan/PEG
Ocular	Diclofenac, poly(acrylic)acid	Sulphadiazine, multiple polymers	Puerarin, poloxamer/ carbopol	Ciprofloxacin, PVA/CMC
Vaginal	Metronidazole, chitosan	Terameprocol, white petroleum	Amphotericin, pluronic	ALA, PMVE/MA
Rectal	Ramosetron, carbopol	Zinc oxide, petroleum	Quinine, HPMC	N/A

3. Mechanism of Mucoadhesion

The process by which certain macromolecules adhere to the mucous tissue surface is not well understood. To create close contact and enhance surface contact, the mucoadhesive must extend throughout the substrate. This will encourage the diffusion of its chains within the mucus. Both repulsion and attraction forces exist, and for a mucoadhesive to work, attraction forces need to be stronger.

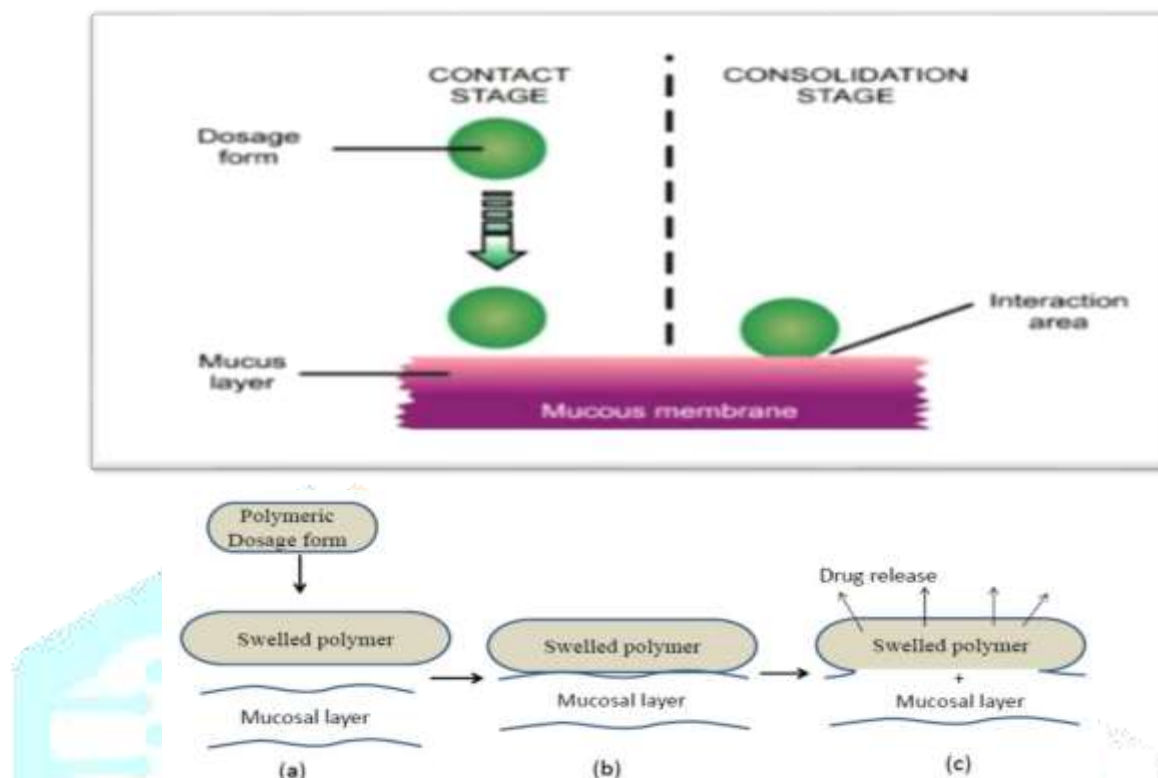


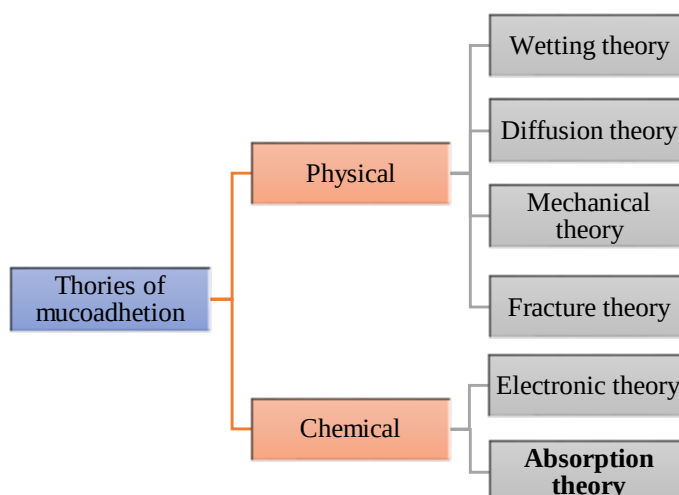
Fig 3: Mechanism of mucoadhesion

Contact and consolidation are the two main phases of the mucoadhesion mechanism. In the first stage, the mucoadhesive and mucus membrane come into contact, causing the formulation to expand and swell and begin making deep contact with the mucus layer. starting in close proximity to mucus layer. The delivery method is sometimes mechanically affixed to the membrane, as in the case of ocular or vaginal formulations.

When the particle gets close to the mucosal surface, it encounters both attractive (van der Waals forces and electrostatic attraction) and repulsive (osmotic pressure, electrostatic repulsion, etc.) forces. The particles must thus get beyond this repellent barrier. Moisture activation of the mucoadhesive components occurs during the second step of consolidation. Because moisture plasticizes the solution, the mucoadhesive molecules can separate and bind together via weak van

Three steps can be used to characterize the mechanism of mucoadhesion between hydrogels and the mucosa.

1. Swelling and dampness.
 2. The bioadhesive polymer's penetration
 3. The creation of weak hydrogen and der Waals chemical bonds
- 4.1. Theory of mucoadhesion



4.1.1. Wetting theory

It takes into account surface and interfacial energy and is primarily used in liquid systems. This refers to a liquid's capacity to adsorb onto a surface on its own as a necessary condition for adhesion formation. By measuring the liquid's contact angle with the surface using methods like contact angle goniometry, one can determine a liquid's affinity for a surface. The general rule is that the lower the contact angle, the greater the affinity of the liquid to solid.

The wetting theory is applicable to liquid systems that spread over surfaces because of their affinity for them. The contact angle is one measurement method that can be used to determine this affinity. Generally speaking, affinity increases with decreasing contact angle (Figure 1). A contact angle that is equal to or nearly equal to zero will provide for sufficient spread ability.

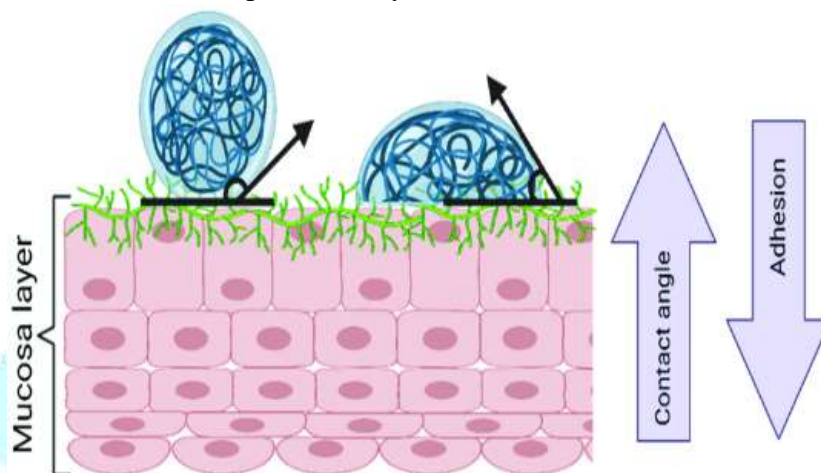


Fig 4: Influence of contact angle on mucoadhesion

4.1.2. Diffusion theory

The diffusion theory explains how the polymer and mucin chains interpenetrate deeply enough to form a semi-permanent adhesive bond, which is thought to get stronger as the polymer chains penetrate farther. The diffusion coefficient, the kind and flexibility of the mucoadhesive chains, mobility, and contact time all affect this penetration rate. The literature states that a depth of interpenetration between 0.2 and 0.5 μm is necessary to create an effective bioadhesive connection.

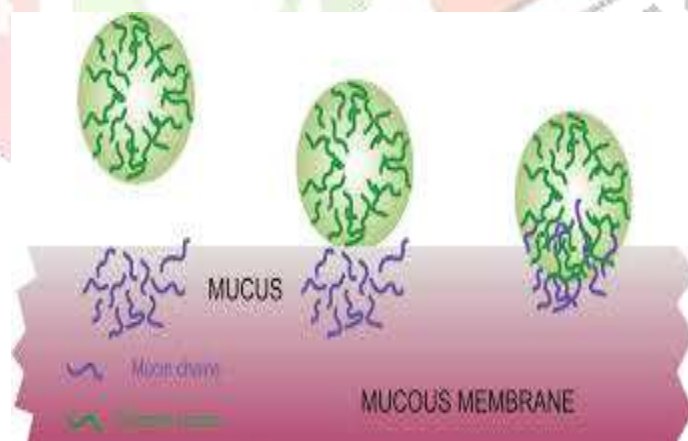


Fig 5: The Interpenetration Of Both Polymer And Mucin

4.1.3. Absorption theory

Adhesion is the outcome of many surface contacts (primary and secondary bonding) between the sticky polymer and the substrate, according to the adsorption theory. The materials adhere after the first contact between the two surfaces due to surface forces between the chemical structures at those two surfaces. Polar groups or molecules reorient themselves at the interface when they are present. Primary bonds created by chemisorption lead to ionic, covalent, and metallic bonding-induced adhesion, which is typically undesired because of their permanence. Particularly strong adherence can lead to chemisorption. According to the notion, one or more secondary forces, including van der Waal's forces, hydrogen bonding, and hydrophobic bonding, are ultimately responsible for adherence to tissue.

4.1.4. Electronic theory

The foundation of this theory is the idea that biological and mucoadhesive materials have opposing electrical charges. As a result, a double electronic layer forms at the interface when the two materials come into contact and exchange electrons. Such a process ultimately results in the creation of attractive forces inside this double layer.

4.1.5. Fracture theory

Perhaps the most widely applied theory in research on the mechanical measurement of mucoadhesion is this one. Following the establishment of adhesion, it examines the force needed to separate the two surfaces. This force, S_m , is commonly determined in resistance to rupture tests by dividing the total surface area (A_0) involved in the adhesive interaction by the greatest detachment force (F_m).

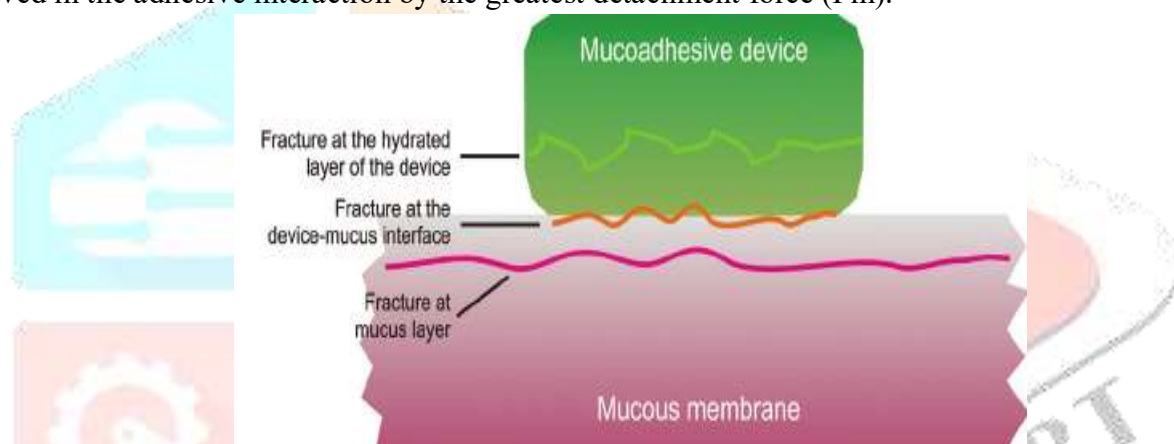


Fig 6: Fractures occurring for mucoadhesion

4.1.6. Mechanical Theory:

When fluid cement interlocks into irregularities on an unsightly floor, this concept accepts an attachment emergency. But tough floors also allow for interaction and a better viscoelastic and plastic strength dissipation at a certain point in joint failure, which are thought to be more important in the adhesion method than a mechanical effect.

5. Mucoadhesive Materials

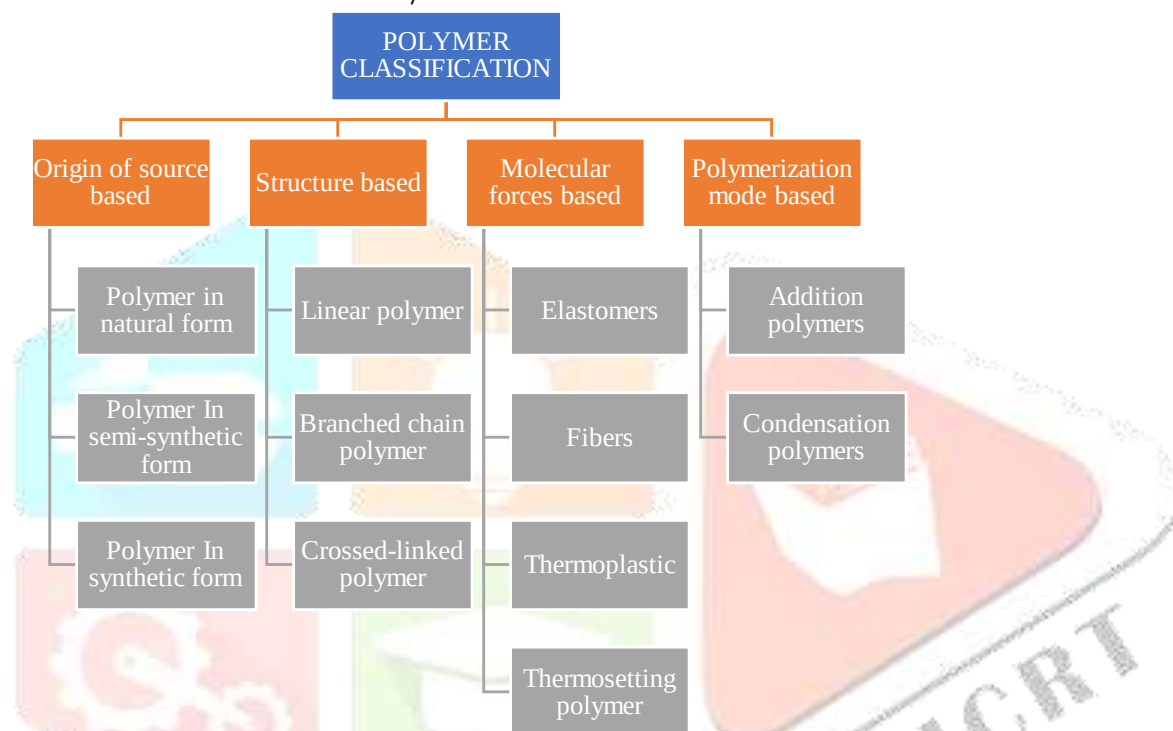
Mucoadhesive polymers contain a variety of hydrophilic groups, including amide, sulfate, carboxyl, and hydroxyl groups. These groups bind to mucus or the cell membrane by a variety of mechanisms, including hydrophobic or electrostatic contacts and hydrogen bonding. Polymers swell in water due to these hydrophilic groups, exposing the greatest amount of sticky sites.

An ideal polymer for a bioadhesive drug delivery system should have the following characteristics

1. It should be nontoxic and nonabsorbable, as should the polymer and its breakdown products.
2. It must not irritate.
3. It should ideally create a robust noncovalent connection with the surface of the mucus or epithelial cells.
4. It should have site-specificity and attach to moist tissues rapidly.
5. This should make it simple to incorporate the medication and provide no obstacles to its release.
6. During storage or the dosage form's shelf life, the polymer cannot break down.
7. To maintain the produced dosage form's competitiveness, the polymer's cost should not be excessive.
8. The active compound needs to be heavily injected into it.
9. An increase in the delivery-absorption site's aquatic biological environment.

10. For proper adherence, it interacts with mucus or its constituents.
11. They permitted the regulated release of the active chemical as they swelled.
12. Either be eliminated unchanged or undergo biological degradation into non-toxic, inactive oligomers.
13. The chain time should be long enough to encourage interpenetration, but not long enough to cause diffusion issues.
14. Because of the development of slippery mucus, excessive hydration reduces mucoadhesive force.
15. At low pH values, mucoadhesion is most advantageous; however, at higher pH values, an extrusion within the conformation transforms the region proper into a rod-like form, increasing their availability for interpenetration and interdiffusion. Absolutely charged polymers, like chitosan, display significant mucoadhesive forces and form polyelectrolyte complexes with mucus at very long pH values²¹.
16. Polymer concentration: to enhance mucoadhesive power, a maximum favorable interest is sought. Although it is based on the dosage form,

6. Classification of Mucoadhesive Polymer



6.1. Based on the source origin

1. Natural Polymer :—they are isolated from natural materials are called natural polymers. E.g.: Cotton, silk, wool, Rubber, Chitosan, Alginate, etc
2. Synthetic Polymer :— these are synthesized from low molecular weight compounds are called Synthetic Polymers. For example, polyethylene, nylon, terylene, polyacrylic acid, and polyethylene glycol.
3. Semisynthetic Polymers : These polymers are commonly derived from polymers that occur via chemical modification. E.g.: Rayon, hydroxypropyl methylcellulose²²

6.2. Based on structure

1. Linear polymers: Molecules form prolonged chains without branches. ¹²
2. Branched Polymer:- Molecules with branch elements that are part of three or more segments.
3. Cross-Linked Polymer:- It includes interconnections amongst chains²³

6.3. Based on molecular force

1. Elastomer: A polymer with highly inclined intermolecular forces and viscoelasticity. Thus, they're famously known as elastic polymers. E.g., Natural rubber Polyurethanes, Silicone, Neoprene
2. Fibers:- A "fibre" is defined as any product capable of being woven or otherwise made proper right into a material. It may be belief of due to the fact the smallest visible unit of material production 'or' a fibre can be defined as a pliable hair like strand that is very small in diameter close to its period
3. Thermoplastics: All plastic materials that can be softened and melted via heating, but they set yet again, even as cool, are called thermoplastics.
4. Thermosetting polymers: Thermosetting plastics are polymers that can be semi-fluid in nature, with low molecular masses. When heated, they start by skip-linking among the polymer chains, making

them difficult and infusible. They form a three-D form in the software program of heat. This reaction was irreversible. The most common example of a thermosetting polymer is that of Bakelite, which is applied in electric-powered insulation.

7. MUCOADESIVE FORMULATION :-

It uses a variety of dose formulations that deliver sustained and localized release at the mucosal surfaces. The following formulas are frequently utilized in mucosal systems.

1. Films and Strips:-

Films and strips were applied to the mucosal surfaces. They deliver drugs directly to the target site, such as the buccal and sublingual mucosae

Advantages

Simple to use and take off

comfortable to wear

increased absorption of drugs because of the huge surface area

Disadvantages

restricted ability to load drugs

Variable drug release as a result of shifting environmental factors

Formulation is difficult.

2. Gels and Pastes:-

These are viscous formulations that are topically applied to mucosal surfaces

Advantages

These include spreading across the mucosal surface and being simple to apply.

high capacity for drug loading,

provide long-term medication release,

Disadvantages:

Some restrictions include a short residence period and

the potential for leakage from the application site,

which may result in discomfort and localized irritations

3. Inserts and Suppositories:-

These are solid or semi-solid dosage forms that are inserted inside the body cavity, such as the vagina or rectum, and adhere to the mucosal surfaces for prolonged drug release.

Advantages

Prolonged drug release,

Most suitable for localized treatment,

Offers sustained therapeutic levels at target site.

• Disadvantages:

It has some limitations are Limited drug retention,

Limited drug loading capacity,

Insertions may be uncomfortable.

4. Patches:-

These adhesives are applied to skin or mucosal surfaces for transdermal and buccal drug delivery.

Advantages of Patches :

Prolonged drug release.

Sustained therapeutic levels.

Controlled and predictable drug delivery system.

Convenient and noninvasive applications.

• Disadvantages:

It also has limitations, such as limited drug-loading capacity.

The adhesive may irritate the skin.

Challenges in maintaining adhesion for extended periods.

5. Implants:-

Implants are solid devices that are placed inside the body cavity for sustained drug release. They adhere to the mucosal surface and release the drug gradually,

• Advantages of implants:

Extended drug release over a long period.

Localized and targeted drug actions.

Potential for tunable release rate and tailored therapy.

• Disadvantages:

Risk of infection.

Limited flexibility in adjusting drug release once implanted.

Invasive implantation procedure.

8. Factors affecting transmucosal permeability

1) Mucus layer:

Drug absorption is impeded by the mucus layer that covers the mucosal surfaces. The mucosal site can influence the mucus layer's thickness and composition, which can impact the permeability of drugs.

2) Epithelial cells:

Drug permeability is also regulated by the epithelial cells that make up the mucosal barrier. Drug transport across the epithelium may be influenced by the expression of transport proteins and the tightness of the junctions between epithelial cells.

3) Drug properties:

The physicochemical properties of the drug itself, such as molecular weight, lipophilicity, and charge, can also affect its ability to penetrate the mucosal barrier.

4) Formulation factors:

Transmucosal permeability may potentially be impacted by the MDDS formulation. The release and penetration of medications into mucosal tissue can be impacted by the selection of mucoadhesive polymers, excipients, and drug delivery systems.

8.1. Strategies to enhance transmucosal permeability

I. Mucoadhesive polymers:

Mucoadhesive polymers can increase the residence time of MDDS on the mucosal surface, providing more time for drug absorption.

II. Permeation enhancers:

Permeation enhancers can temporarily disrupt the mucosal barrier, thereby allowing increased drug penetration. However, the use of permeation enhancers must be carefully considered because of potential safety concerns.

III. Nanocarriers:

Nanocarriers, such as liposomes or nanoparticles, can encapsulate drugs and protect them from degradation while also facilitating their transport across the mucosal barrier.

IV. Physical methods:

Physical methods such as iontophoresis or electroporation can be used to enhance drug transport across the mucosal barrier by applying an electrical current or voltage.

9. THE PERSPECTIVES OF THE PRESENT AND THE FUTURE:

Drug administration has been completely transformed by mucoadhesive drug delivery systems (MDDS), which provide a patient-friendly, non-invasive method of delivering drugs straight to mucosal surfaces. Compared to conventional oral or injectable methods, these systems offer a number of benefits, such as the following.

1. Localized drug delivery

By adhering to the mucosal surface, MDDS maximize therapeutic effects and minimize systemic exposure and negative effects while facilitating targeted drug release at the site of action.

2. Sustained drug release:

MDDS can reduce the frequency of doses and maintain therapeutic medication levels by providing prolonged drug release over an extended period of time.

3. Improved patient compliance:

Patient adherence to treatment plans is improved by MDDS's easy and comfortable administration.

The future of Mucosal Drug Delivery Systems holds significant promise and potential for development.

There is a lot of hope and development potential for mucosal drug delivery systems in the future.

- **Personalized Mucosal Therapies:** Precision medicine developments are probably going to make it possible to create customized MDDS formulations that will allow for drug administration that is tailored to the requirements of each patient.
- **Biologics and Nanotechnology:** It is anticipated that biologic therapies and nanoparticles will revolutionize MDDS by offering precise and regulated medication delivery for complicated illnesses.
- **Vaccine Delivery:** It is expected that MDDS will be essential to the delivery of vaccines, potentially helping to improve patient compliance and immunity in the case of COVID-19 and other infectious diseases.
- **Telemedicine and Remote Monitoring:** By integrating with telemedicine and remote patient monitoring, MDDS can allow medical professionals to conduct and oversee treatments remotely.
- **Improved medication Delivery Devices:** Real-time data and better patient adherence are anticipated with the introduction of intelligent, networked medication delivery devices.

10. Application of the mucosal drug delivery system:

1. Oral mucoadhesive drug administration offers the benefits of low enzymatic activity and great accessibility for a variety of medications that, when administered orally, have poor bioavailability and are quickly broken down. Prior to now, periodontal disorders were treated using hydrophilic polymers such as SCMC, HPC, and polycarbophil. However, the focus is currently on using these systems effectively to transport proteins, polysaccharides, and peptides.
2. High patient compliance is another benefit of the buccal cavity. A first-generation mucoadhesive material called Orabase has been utilized as a mouth ulcer barrier. Tablets have also been developed, however semisolids are easier to administer. Tablets can be multilayered systems with a mucoadhesive agent or matrix devices. To prevent the salivary gland's clearing mechanism, the tablet is kept beneath the upper lip. This method is typically used to deliver Buccostem, a sticky antiemetic pill that contains prochlorperazine.
3. There are three types of buccal mucoadhesive dose forms: A single-layer device that releases drugs in multiple directions. A double-layered device that prevents loss from the top surface of the dosage form into the oral cavity by superimposing an impermeable backing layer on top of a drug-loaded bioadhesive layer

CONCLUSION

A promising new method of drug delivery is MDDS. Avoiding first-pass metabolism, increasing medication bioavailability, decreasing dosage frequency, and improving patient compliance are only a few benefits over conventional drug delivery methods. From small compounds to biologics, the mucosal drug delivery system has a lot of potential for a variety of uses, especially for chronic illnesses and conditions that call for targeted or sustained release. In order to potentially change the drug delivery landscape, future research should concentrate on overcoming present constraints and creating formulations that are optimized to certain therapeutic needs.

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