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# Mucosal Drug Delivery system

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## ABSTRACT

**Purpose:** The aim of this article is to present a review of mucoadhesive drug delivery system.the review covers the mucoadhesive concepts,polymers used,theories and mechanisms of mucoadhesion,and factors affecting the mucoadhesive dosage forms.

To overcome the relatively short gastrointestinal (GI) time and improve localization for oral controlled or sustained release drug delivery systems, bioadhesive polymers that adhere to the mucin/epithelial surface are effective and lead to significant improvement in oral drug delivery. Improvements are also expected for other mucus-covered sites of drug administration. Bioadhesive polymers find application in the eye, nose, and vaginal cavity as well as in the GI tract, including the buccal cavity and rectum. This article lays emphasis mainly on mucoadhesive polymers, their properties, and their applications in buccal, ocular, nasal, and vaginal drug delivery systems with its evaluation methods. Mucoadhesive dosage forms may be designed to enable prolonged retention at the site of application, providing a controlled rate of drug release for improved therapeutic outcome.

Application of dosage forms to mucosal surfaces may be of benefit to drug molecules not amenable to the oral route, such as those that undergo acid degradation or extensive first-pass metabolism. The mucoadhesive ability of a dosage form is dependent upon a variety of factors, including the nature of the mucosal tissue and the physicochemical properties of the polymeric formulation. This review article aims to provide an overview of the various aspects of mucoadhesion, mucoadhesive materials, factors affecting mucoadhesion, evaluating methods, and finally various mucoadhesive drug delivery systems (buccal, nasal, ocular, gastro, vaginal, and rectal).

Keywords- Bioadhesive,Degradation, polymers ,Mucoadhesive , Evaluation, physicochemical, mucin

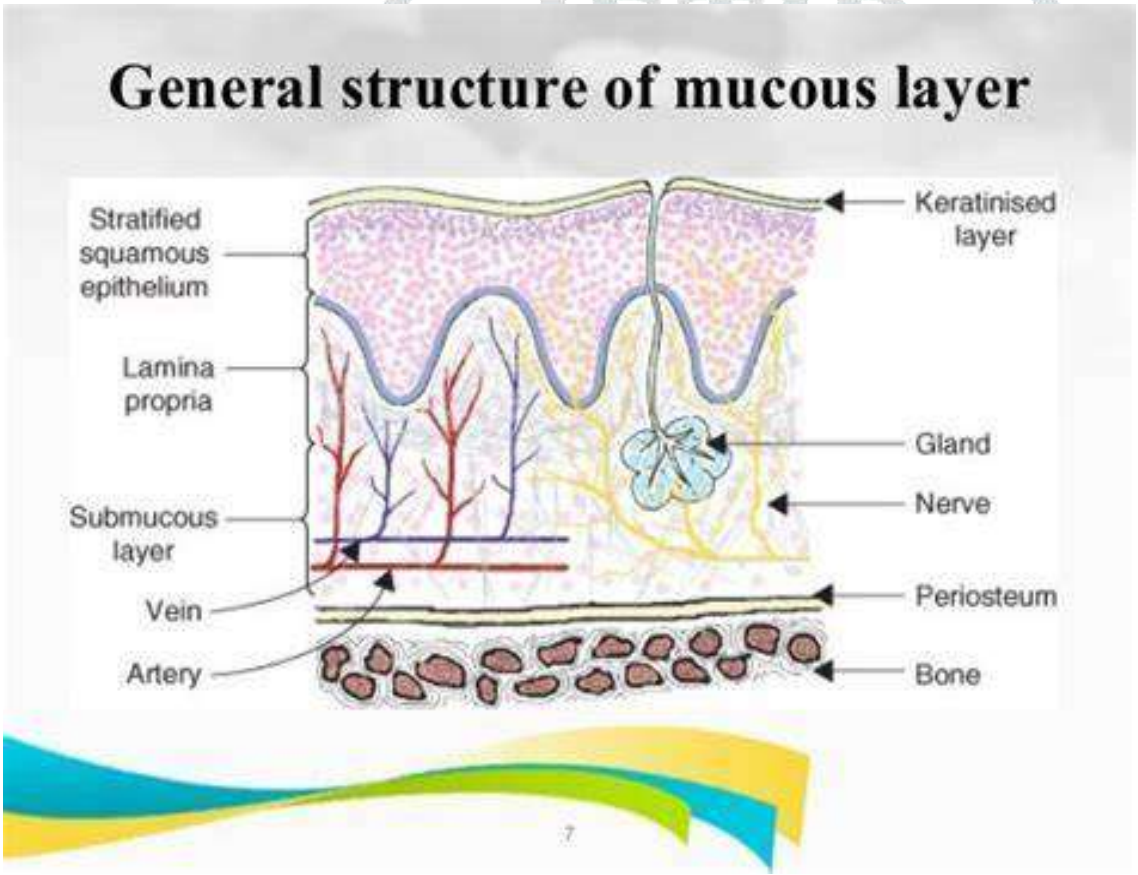
## INTRODUCTION

Mucosal drug delivery system is a type of drug delivery system that targets the mucosal membranes such as the lining of the mouth,vagina,and bladder.this system provides intimate contact between the dosage form and the absorptive mucosa and ensures a high drug concentration in the local treatment of deseases.the mucosal drug delivery system is designed to increase the residential time of the formulation at the site of administration for better absorption.the formulation interacts with the mucosal layer to provide controlled/sustained release of drug at the site of administration.

the bioadhesive/mucoadhesive properties of these system allow them to adhere to biological tissues for an extended period of time,thus providing site-specific action by localization of the drug delivery system in a particular regionthe ideal characteristics of a mucosal drug delivery system include rapid adherence to the mucosal membrane without changing the physical property of the delivery system,biodegradable,non-toxicity,and enhancement of penetration of the active agent. is a specialized drug delivery system that involves delivering drugs through various mucosal surfaces in the body, including the nasal, oral, buccal, ocular, vaginal, and rectal routes.

This route of drug administration offers several advantages over traditional routes such as oral and parenteral administration, including improved patient compliance, enhanced drug absorption, local and systemic drug delivery, avoidance of first-pass metabolism, and reduced side effects.

The mucosal surfaces in the body are covered with a layer of epithelial cells, which provide an effective barrier against the entry of foreign substances. However, these surfaces also possess unique features that make them suitable for drug delivery. For example, the nasal mucosa has a large surface area and rich blood supply, which allows for rapid drug absorption into the systemic circulation.




ADVANTAGES OF ORAL MUCOADHESIVE DRUG DELIVERY SYSTEMS:

• Prolongs the residence time of the dosage form At the site of absorption, hence increases the Bioavailability.

• Excellent accessibility, rapid onset of action.

• Rapid absorption because of enormous blood Supply and good blood flow rates.

• Drug is protected from degradation in the acidic Environment in the git.

• Improved patient compliance.

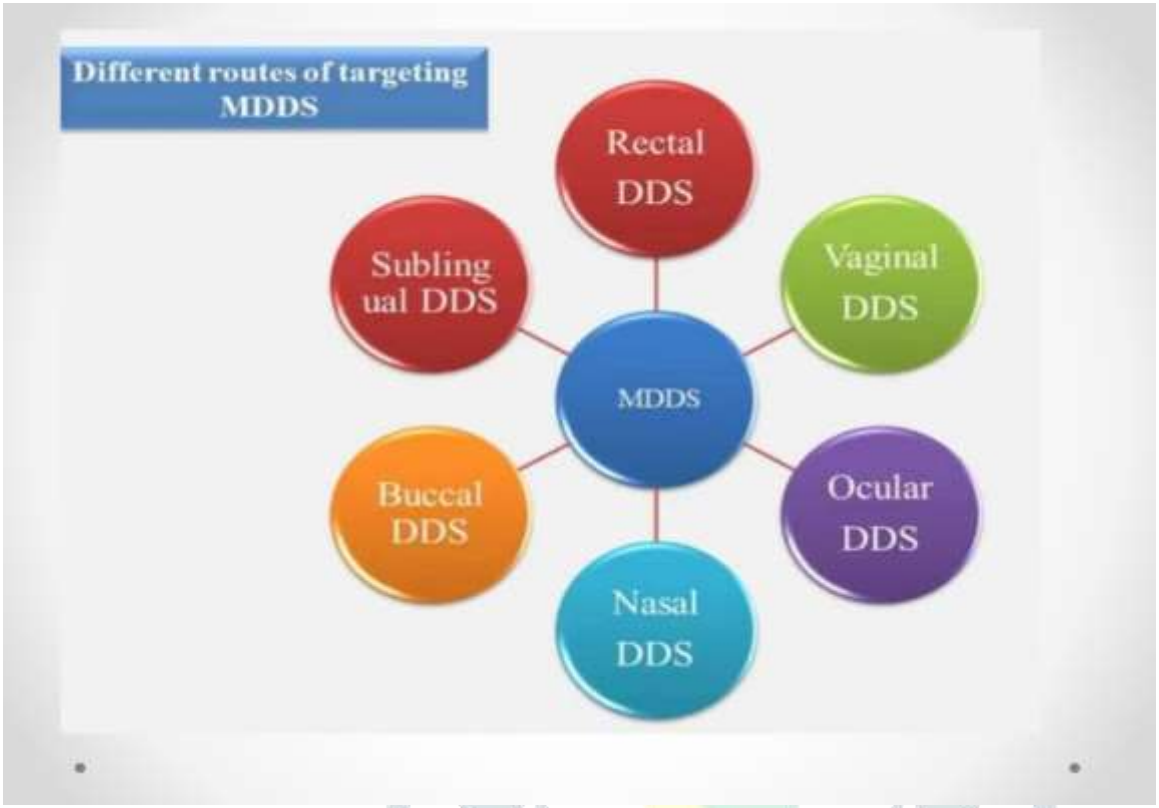
DISADVANTAGES OF MUCOADHESIVE DRUG DELIVERY SYSTEMS:

• Occurrence of local ulcerous effects due to Prolonged contact of the drug possessing Ulcerogenic property.

• One of the major limitations in the development Of oral mucosal delivery is the lack of a good Model for in vitro screening to identify drugs Suitable for such administration.

• Patient acceptability in terms to taste and Irritancy.

• Eating and Drinking is prohibited




# mechanism of mucoadhesion

The mechanism of mucoadhesion is generally divided into two steps: the contact stage and the consolidation stage [Figure 2]. The first stage is characterized by the contact between the mucoadhesive and the mucus membrane, with spreading and swelling of the formulation, initiating its deep contact with the mucus layer.

mechanism of mucoadhesion between hydrogels and mucosa can be described in three steps.

1. Wetting and swelling

2. Interpenetration of the bioadhesive polymer

3. Formation of weak chemical bonds.

Alternatively, mucoadhesion may be described as through contact stage and consolidation stage

Contact stage: is characterized by the contact b/w the mucoadhesive & the mucus membrane with spreading & swelling of the formulation, initiating its deep contact with mucus layer.

Consolidation stage:The,mucoadhesive material is activated by the presence of moisture

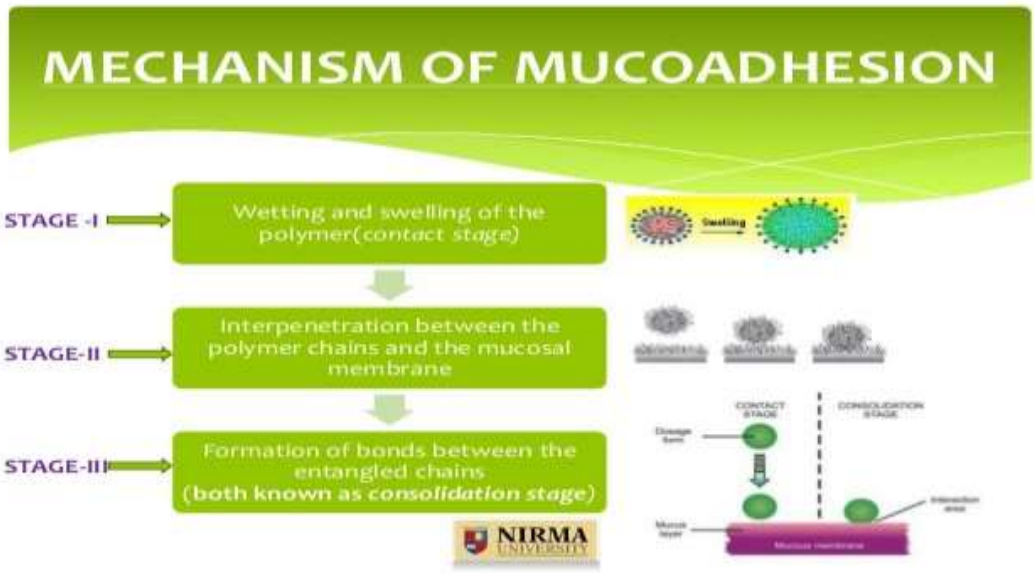



Figure.2

## Polymers in Mucosal Drug Delivery

Mucoadhesive delivery systems are being explored for the localization of the active agents to a particular location/site.

Polymers have played an important role in designing such systems so as to increase the residence time of the active agent at the desired location. Polymers used in mucosal delivery system may be of natural or synthetic origin. In this section we will briefly discuss some of the common classes of mucoadhesive polymers.

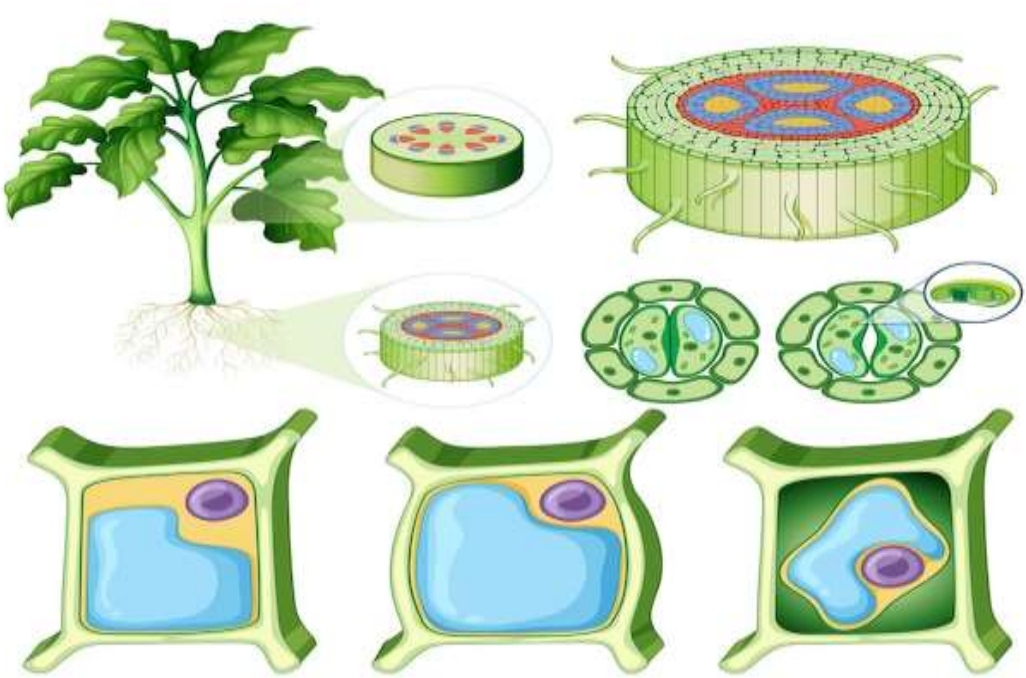
### Polymers Used in Mucoadhesive Drug Delivery System:

Mucoadhesive polymers are water-soluble and water insoluble polymers that adhere to the mucin-epithelial surface to provide prolonged contact time at the site of absorption. Ideal mucoadhesive polymer should be nontoxic, non-irritant and non-absorbable, adhere quickly to mucosa, inexpensive, stable during the shelf life, and build a strong non-covalent bonds with the mucin-epithelial cell surfaces(Bernkop-Schnürch, 2005; Mythri, Kavitha, Kumar, & Singh, 2011).

Table 1: Classification of mucoadhesive polymers(Brannigan & Khutoryanskiy, 2019; Grabovac, Guggi, & Bernkop-Schnürch, 2005; Wang & Ye, 2010)

| criteria | category | example |
|---|---|---|
| Source | natural | Chitosan, Agarose, Hyaluronic acid, Gelatin, Pectin, Tragacanth,Gums (guar, Karaya, Xanthan, etc.) |
| | synthetic | Sodium Carboxy Methyl Cellulose (SCMC), methyl cellulose, Carboxy Methyl Cellulose (CMC),poly (vinyl pyrrolidone), Poly (dimethyl siloxane), Poly acrylic acid-based polymers (Polyacrylates, Carbopol, polyethylene glycol, etc.) |
| Solubility | Water soluble | Carbopol, poly (vinyl pyrrolidone), Sodium carboxy methyl cellulose, polyacrylic acid, Pectin, xanthan gumandSodium alginate. |
| | Water insoluble | Chitosan, polycarbophil, ethyl cellulose |
| Charge | anionic | Chitosan, Sodium alginate, Carbopol, Xanthan gum, Pectin, polycarbophil. |
| | cationic | Chitosan,amino dextran,polysene,dimethylaminoethyl dextran |
| | Non-ionic<br>neutral | Poly vinyl alcohol , hydroxyl propyl cellulose,hydroxyl ethyl starch,poly vinyl pyrrolidone |

Hydrophilic Polymers



The polymers in this category are soluble in water. Matrices developed with these polymers swell when put into an aqueous media with subsequent dissolution of the matrix. The polyelectrolytes exhibit greater mucoadhesive properties when compared with neutral polymers. Anionic polyelectrolytes, e.g., poly(acrylic acid)and carboxymethyl cellulose, have been extensively used for designing mucoadhesive delivery systems due to their ability to exhibit strong hydrogen bonding with the mucin present in the mucosal layer. Chitosan provides an excellent example of a cationic polyelectrolyte, which has been extensively used for developing mucoadhesive polymer due to its good biocompatibility and biodegradable properties.

Chitosan undergoes electrostatic interactions with the negatively charged mucin chains thereby exhibiting mucoadhesive property. The ionic polymers may be used to develop ionic complex with the counterionic drug molecules so as to have a drug-delivery matrix exhibiting mucoadhesive property. a partially neutralized poly(acrylic acid) complex was developed in the presence of levobetaxolol hydrochloride, a potent cardiac βblocker. The delivery system was prone to dissolution as the time progressed due to the release of the incorporated drug .

Mucoadhesive microcapsules can be designed with same principle by using orifice-ionic gelation method. This technique has been propertie design a delivery system of gliclazide, an anti-diabetic drug, using sodium alginate,sodium carboxymethyl cellulose, carbopol 934P and hydroxy propylmethyl cellulose. The delivery system showed the release of gliclazide for an extended period of time due to its mucoadhesive properties.

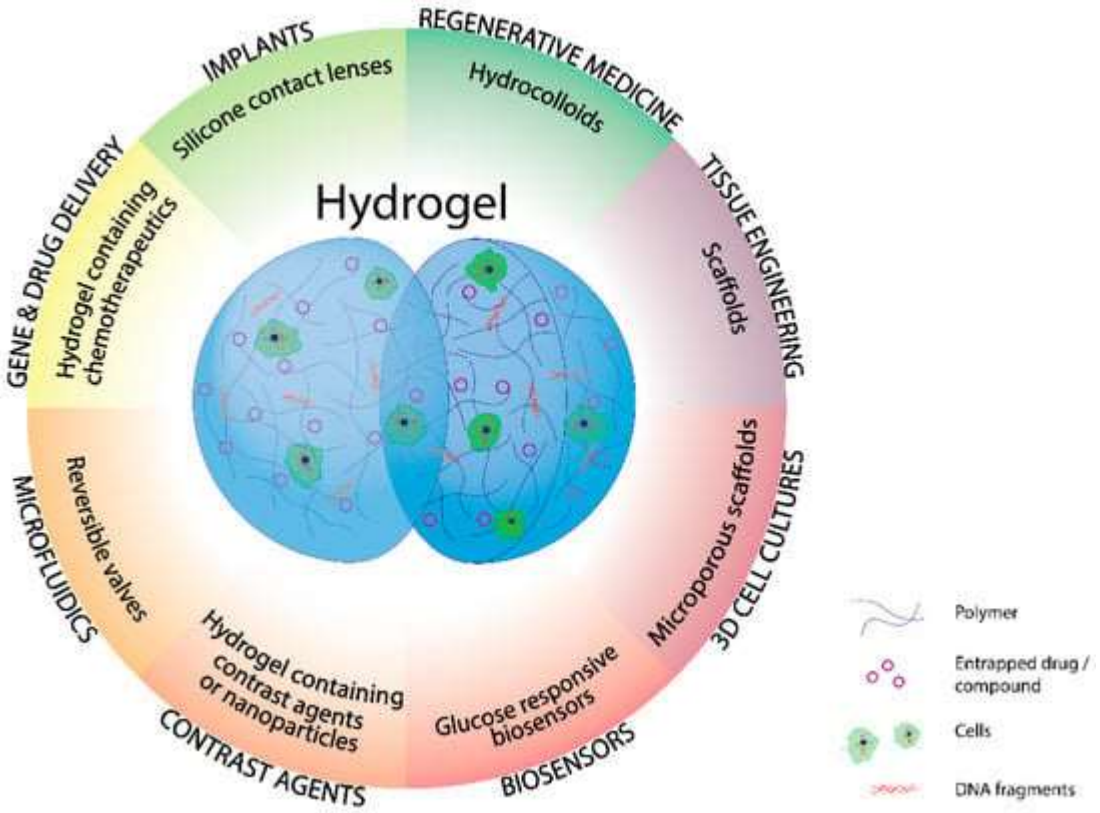
Non-ionic polymers, e.g., poloxamer, hydroxypropyl methyl cellulose, methyl cellulose, poly(vinyl alcohol) and poly(vinyl pyrrolidone), have also been used for mucoadhesive properties The hydrophilic polymers form viscous solutions when dissolved in water and hence may also be used as viscosity modifying/enhancing agents in the development ofliquid ocular delivery systems so as to increase the bioavailability of the active agents by reducing the drainage of the administered formulations

These polymers may be directly compressed in the presence of drugs so as to have a mucoadhesive delivery system Numerous polysaccharides and their derivatives like chitosan, methyl cellulose,hyaluronic acid, hydroxypropyl methylcellulose, hydroxypropyl cellulose, xsystemgum, gellan gum, guar gum and carrageenan have found applications in ocular mucoadhesive delivery systems.Cellulose and its derivates have been

reportedto have surface active property in addition to its film forming capability.Cellulose derivatives with lower surface acting property are generally preferred inocular delivery systems as they cause reduced eye irritation. Of the various cellulose derivates, sodium carboxymethyl cellulose has been found to have excellent ocular mucoadhesive property. Cationic cellulose derivatives (e.g., cationic hydroxyethyl celluloses) have been used in conjunction with various anionic polymers for the development of sustained delivery systems.

## Hydrogels

Hydrogels can be defined as three-dimensionally cross-linked polymer chains which have the ability to hold water within its porous structure. The water holding capacity of the hydrogels is mainly due to the presence of hydrophilic functional groups like hydroxyl, amino and carboxyl groups. In general, with the increase in the cross-linking density there is an associated decrease in the mucoadhesion. Thielmann et al. reported the thermal cross-linking of poly(acrylic acid) and methyl cellulose. They reported that with the increase in the cross-linking density,there was a reduction in the solubility parameters and swelling which resulted in reduction of mucoadhesion. Hydrogels prepared by the condensation reaction of poly(acrylic acid) and sucrose indicated an increase in the mucoadhesive property with the increase in the cross-linking density and was attributed to increase in the poly(acrylic acid) chain density per unit area. Acrylates have been usedto develop mucoadhesive delivery systems which have the ability to deliver peptide bioactive agents to the upper small intestine region without any change in the bioactivity of the peptides. In a typical experimentation, Wood and Peppas developed a system in which ethylene glycol chains were grafted on methacrylic acid hydrogels and were subsequently functionalized with wheat germ agglutinin. Wheat germ agglutinin helped in improving the intestinal residence time of the delivery system by binding with the specific carbohydrate moieties present in the intestinal mucosa[74]. In addition to the drug targeting, mucoadhesive hydrogel based formulations for improving the bioavailability of the poorly water-soluble drug. Muller and Jacobs prepared a nanosuspension of buparvaquone, a poorly water-soluble drug, byincorporating it within carbopol and chitosan based hydrogels.




The mucoadhesivedelivery systems showed improved bioavailability of the drug when compared over the nano suspension. This was attributed to the increased retention time of the delivery system within the gastrointestinal suspension

## Thiolated polymer

The presence of free thiol groups in the polymeric skeleton helps in the formation of disulphide bonds with that of the cysteine-rich sub-domains present in mucin which can substantially improve the mucoadhesive properties of the polymers (e.g.,poly(acrylic acid) and chitosan) in addition to the paracellular uptake of the bioactive agents.

Various thiolated polymers include chitosan– iminothiolane,poly(acrylic acid)–cysteine, poly(acrylic acid)–homocysteine, chitosan–thioglycolic acid, chitosan–thioethylamidine, alginate–cysteine, poly(methacrylic acid)–cysteine and sodium carboxymethylcellulose–cysteine.

### Based Lectin-Polymers

Lectins are proteins which have the ability to reversibly bind with specific sugar/carbohydrate residues and are found in both animal and plant kingdom in additionto various microorganisms. Many lectins have been found to be toxic and immunogenic which may lead to systemic anaphylaxis in susceptible individuals on subsequent exposure.

The specific affinity of lectins towards sugar or carbohydrate residues provides them with specific cyto-adhesive property and is being explored to develop targeted delivery systems. Lectins extracted from legumes have been widely explored for targeted delivery systems.

The various lectins which have shown specific binding to the mucosa include lectins extracted from Ulex europaeusI, soybean, peanut and Lens culinarius.

The use of wheat germ agglutinin has been on the rise due to its least immunogenic reactions, amongst available lectins, in addition to its capability to bind to the intestinal and alveolar epithelium and hence could be used to design oral and aerosol delivery system .

### There are several examples of mucoadhesive drug delivery systems. Here are a few:

1.**nasal mucoadhesive microspheres of lercanidipine** :these microspheres have been prepared to improved systemic bioavailability and antihypertensive activity.

2**.tenolol-releasing buccal patches**:these patches have been formulated to avoid extensive drug first-pass metabolism.

3**.tenofovir mucoadhesive vaginal tablet**:these hydrogen has been prepared to prolong duration of action and increase bioavailability of anti-inflametry tolmetin.

4.**rectal mucoadhesive hydrogels**:this hydrogels has been prepared to prolong duration of action and increased bioavalibilty of anti-inflametry tolmetin.

Example:

1**.Lercanidipine** is a calcium channel blocker used to treat hypertension . it works by relaxing blood vesssels,which lowers blood pressure .the recommended adult dosage is 10 mg once a daily,which can be increased to 20 mg daily after two weeks if needed.Lercanidipine should be taken by orally on an empty stomach.

The brand names of lercanipidine available in india,including lotensyl,lerka (10mg), lerka (20mg),aristo larpin,larpin ,lervasc(10mg), ,lervasc(20mg),larpin(10mg),lerez(20mg),and landip-10

## Mechanism of lercanidipine:

Lercanidipine is a calcium channel blockers that belong to the dihydropyridine class of calcium channel blockers.

It works by blocking L-type calcium channel in the smooth muscle cells of blood vessels,which relaxes them and lowers the blood pressures. This allows blood to circulate more freely around the body, which in turns allows the heart to work more efficiently.

Lercadipine acts more slowely than older dihydropyridines,but it probably has fewer adverse effects.


The active substance is lercanidipine hydrochloride. One 10 mg film-coated tablet contains 10 mg lercanidipine hydrochloride; equivalent to 9.4mg lercanidipine.

One 20mg film coated tablet contains 20 mg lercanidipine hydrochloride;equivalent to 18.8 mg lercanidipine.

## The other ingredients are:

1.Tablet core: Magnesium stearate,providone,sodium starch glycolate (Type A,lactose monohydrate,microcrystalline cellulose.

2.Film coating 10 mg tablets: Macrogol,polyvinyl alcohol,talc,titanium dioxide (E 171), yellow iron oxide(E172),

Film coating 20 mg tablets:Macrogol,polyvinyl alcohol,talc,titanium dioxide (E171), yellow iron oxide(E172),red iron oxide(E172),

## Uses

Lercanidipine is a medication used to treat high blood pressure (hypertension)and to prevent angina (heart related chest pain)1.it is a calcium channel blocker that helps to lower blood pressure and reduce the workload of the heart,which helps prevent heart attacks and strokes.

## Side effect of lercanidipine

Fatigue, ankle swlling, Sleepiness, Flushing, Headache, Nausea, dizziness, palpitations, edema(swelling), Abdominal pain

Note- lercanidipine is contraindicated in pregnancy and lactation and in patients with uncontrolled heart failure.

## FACTORS EFFECTING MUCOADHESIVE DRUG DELIVERY SYSTEM

1.Molecular weight:The mucoadhesive force increases with molecular weight of polymer, up to 1, 0000 and beyond This level there is no much effect.

2.Concentration of Active polymers

For solid dosage forms such as tablets showed that the higher the polymer concentration the Stronger the mucoadhesion. There is an optimum concentration of polymer corresponding to The best mucoadhesion.

1.Flexibility of Polymer chain

Flexibility is an important factor for interpenetration and enlargement.

3.Environment Related factors

1.pH:pH influences the charge on the surface of both mucus and the polymers.

2.srenght:Applied strength To place a solid mucoadhesive system, it is necessary to apply a defined strength.

3.Initial contact time: The mucoadhesive strength increases as the initial contact time increases.

4.Swelling: Swelling depends on both polymers concentration and on presence of water.

4.Physiological Variables

1.Mucin turn over:The mucin turnover is expected to limit the residence time of the mucoadhesive on the mucus Layers.

Diseased state Mucin turnover results in substantial amounts of soluble mucin molecules.

Physicochemical properties of mucus are known to change during diseased states, such as Common cold, gastric ulcers, ulcerative colitis, cystic fibrosis, bacterial and fungal inflections

## MUCOADHESION THEORIES

1.Electronic theory(Vasir, Tambwekar, & Garg, 2003): It is based on the suggestion that both mucoadhesive and biological materials possess opposing electrical charges. Thus, when both materials come into contact, they transfer electrons leading to the building of a double electronic layer at the interface, where the attractive forces within this electronic double layer determine the mucoadhesive strength.

2. Adsorption theory(Woertz, Preis, Breitkreutz, & Kleinebudde, 2013): In this theory, the mucoadhesive device holds fast to the mucous after contact because of surface force acting between the atoms in both surfaces. From this force, a secondary chemical interaction, for example, in van der Waals and hydrogen bonds, electrostatic fascination, or hydrophobic interactions rise.

3. Wetting theory(Rojewska et al., 2017): The wetting theory applies to liquid systems which is the affinity of a liquid to maintain contact in the surface. This affinity can be found by using measuring methods such as the contact angle. The common rule states that the lower the contact angle, the more significant the affinity (Figure 3). For sufficient spreading and completely wetting liquid, contact angle must be zero or close to zero.

The difference between the surface energies γB and γA and the interfacial energy γAB

The greater the individual surface energy of mucus and device concerning the interfacial energy, the greater the adhesion work, WA, i.e., the greater the energy needed to separate the two phases

4. Diffusion theory: Dissemination theory portrays the interpenetration of both polymer and mucin chains to an adequate depth to make a semi-permanent adhesive bond (figure 5). It is accepted that the adhesion force increments with the level of penetration of the polymer chains. This penetration rate relies upon the diffusion coefficient, flexibility, and nature of the mucoadhesive chains, mobility, and contact time. As indicated by the literature, the depth of interpenetration needed to create an effective bioadhesive bond lies in the range 0.2-0.5 µm. This interpenetration depth of polymer and mucin chains can be assessed by the contact time, and Db is the diffusion coefficient of the mucoadhesive material in the mucus.

The adhesion strength for a polymer is reached when the penetration depth is around proportional to the polymer chain size. For diffusion to happen, the components included must have great mutual solubility, that is, both the bioadhesive and the Copyright Journal of Scientific Research in Medical and Biological Sciences (JSRMBS), Under the license CC BY- 4.0 mucous have comparative chemical structures—the more the structural similarity, the better the mucoadhesive bond.

5.Mechanical theory(Yadav, Gupta, Kumar, Yadav, & Kumar, 2010): This theory believes that adhesion is be owing to the filling of the irregularities on a rough surface by the used mucoadhesive liquid. Besides, such irregularity rises the interfacial area existing for the interactions, thus aiding scattering energy and can be considered the most important phenomenon of the process. It is far-fetched that the mucoadhesion process is the same for all cases, and therefore it cannot be described by a solitary theory. All theories are relevant to recognize the critical process variables. The mechanisms regulating mucoadhesion are also influenced by the intrinsic properties of the formulation and by the environment in which it is applied. Inherent factors of the polymer are linked to its molecular weight, concentration, and chain flexibility.

6. Fracture theory:Maybe this is the most-utilized theory in studies on the mechanical estimation of mucoadhesion.it differs the previous theories in it relates the adhesive strength to the forces required for detatchement of the two involved surfaces after adhesion. It analyses the force needed to separate two surfaces after adhesion is established. This force, Sm, is frequently determined in tests of resistance to rupture by the ratio of the maximal detachment force, Fm, and the total surface area, A0, involved in the adhesive interaction.

In a single component uniform system, the fracture force, SJ, which is equivalent to the maximal rupture tensile strength, Sm, is proportional to the fracture energy (GC) for Young's module (E) and to the critical breaking length (c) for the fracture site.

Fracture energy (GC) can be obtained from the reversible adhesion work, Wr (energy required to produce new fractured surfaces), and the irreversible adhesion work, Wi (work of plastic deformation provoked by the

removal of a proof tip until the disruption of the adhesive bond), and both values are expressed as units of fracture surface (Af ).

The elastic module of the system (E) is related to the stress (s) and to the shear (e) by Hooke's law.

the stress is the ratio between force (F) and area (A0), and shear is given by the ratio between the variety of system thickness (Dl) and the original thickness (l 0). A criticism of this analysis is that the system under investigation must Copyright © 2021, Journal of Scientific Research in Medical and Biological Sciences (JSRMBS), Under the license CC BY- 4.0 have known physical dimensions and ought to be constituted by a single and uniform material. For this situation, the equation ought to be expanded to oblige elastic dimensions and modules for each component. Besides, it must be considered that a failure of adhesion will happen at the bioadhesive interface. Nonetheless, it has been demonstrated that the rupture seldom occurs at the surface, however close to it or at the most vulnerable point, which can be simply the interface itself, the mucus layer, or the hydrated region of the mucus, as represented in (Figure 6).Since the fracture theory is concerned distinctly with the force required to isolate the parts, it does not consider the interpenetration or diffusion of polymer chains. Therefore, it is proper for use in the calculations for rigid or semi-rigid bioadhesive materials, in which the polymer chains do not penetrate the mucus layer.

| Drugs | Year | MOA | Route | Uses |
|---|---|---|---|---|
| Antiviral e.g Acyclovir | 1974 | Inhibit viral DNA polymerase by acting as an analog to deoxyguanosine triphosphate (dGTP) | Oral, intravenous | Chickenpox,shingles,herpes virus infection of skin |
| Oromucosal,tablet e.g orodispersible | 1986 | Rapidly disintegrates in the mouth upon contact with saliva | Oral, Buccal sublingual | Used in heart burn and indigestion |
| Nasal Sprays e.g; Rhinocort aqua | Feb 8 2016 | It has high topical anti-inflammatory potency and it is rapidly biotransformed in the liver | Nasal | Treat seasonal and year round allergy symptom |
| NSAIDs e.g;flubiprofen | 1988 | Reversible inhibitor of cyclooxygenase(COX) | orally | Relive,pain tenderness, swelling, stiffness |
| Ophthalmic e.g;systane | 2003 | Product bind to damaged hydrophobic areas of epithelial cells to add volume tear film by forming a protective gel matrix that provide long lasting protection | Topical | Treat symptoms of dry eyes,reduces redness and swelling of the eye |
| Topical ,Cream e.g; luliconazole | 2005 | It works by killing the fungus or yeast by inhibit ergosterol synthesis by inhibiting the enzyme lanosterol demethylase | Topical | Treat infection of tinea cause by fungus or yeast |
| Chewing gum e.g; Guar gum,xanthan gum | 1950 | Guar improves glucose tolerance predominately by reducing glucose absorption in the small intestine | orally | Used in food as thickening agent Used as dietary supplement |
| Salbutamol sulphate | 1966 | Inhibition of bronchial smooth muscle contaction and subsequent bronchodilation | Intravenously , Orally, by inhalation | bronchodilator |
| Vaginal e.g;Metronidazole,chitosan | 1962 | Inhibits protein synthesis by interacting with DNA,and causes a loss of helical DNA tructure and strand breakage | orally | Treat skin infection,also used to treat vaginosis and pelvic |

| | | | | |
|---|---|---|---|---|
| | | | | inflammatory disease |
| Rectal<br>e.g;Ramosetron hcl, Ramosetron ,carbopol | 2008 | It is serotonin 5-HT3 receptor antagonist to treat nausea and vommiting | Orally | Treatment of nausea and vomiting diarrhea |

MUCOADHESIVE DRUG TABLE

# Applications of Mucosal drug Delivery:

Mucosal drug delivery has found applications in various therapeutic areas, including:

Nasal Drug Delivery: Nasal sprays are used for delivering drugs for local treatment of conditions such as allergic rhinitis or for systemic delivery of drugs, including peptide and protein-based therapeutics.

Buccal and Sublingual Drug Delivery: Buccal and sublingual tablets or films are used for delivering drugs that undergo extensive first-pass metabolism, such as nitroglycerin for angina or buprenorphine for pain management. Ocular Drug Delivery: Ophthalmic solutions, suspensions, or ointments are used for delivering drugs to treat eye infections, glaucoma, or ocular inflammation.

Vaginal Drug Delivery:Vaginal drug delivery systems are utilized for localized treatment of infections, contraception, and hormone replacement therapy. Rectal Drug Delivery: Suppositories or enemas are used for delivering drugs for local treatment of conditions such as hemorrhoids or for systemic drug delivery in cases where oral administration is not feasible.

# Conclusion

Mucosal drug delivery system offer unique advantages over traditional routes of Drug Administration providing improved drug absorption targeted drug delivery and reduces side effect the specific mucosal route use depends on the drug ‘s properties and intended therapeutic effect continue research and technological advancement in mucosal drug delivery system hold great promise for enhancing drug Efficacy.

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