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MUCOADHESIVE POLYMER IN NOVEL DRUG DELIVERY: A PROMISING THERAPEUTIC STRATEGY

SHEK BASHEERA BEE, G. SRAVANI, U. MOUNIKA, CHANDU BABU RAO

Priyadarshini Institute of Pharmaceutical Education and Research, 5th Mile, Pulladigunta, Guntur-522017, Andhra Pradesh, India.

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ABSTRACT

Mucoadhesive drug delivery systems are designed to adhere to the mucosal surfaces of the body by interacting with the mucus layer and mucin glycoproteins, thereby enhancing the residence time of drug formulations at the site of absorption. This prolonged contact improves drug bioavailability, enables controlled and sustained drug release, and reduces dosing frequency, ultimately enhancing patient compliance. This review highlights the mechanisms and theories of cohesion, factors affecting mucoadhesive performance, types of mucoadhesive polymers, and recent developments, emphasizing their potential in targeted and patient-friendly drug delivery mucoadhesive systems have found wide applications in buccal, nasal, ocular, vaginal, and gastrointestinal drug delivery, particularly for peptides, proteins, and vaccines. This review highlights the mechanisms and theories of cohesion, factors affecting mucoadhesive performance, types of mucoadhesive polymers, and recent developments, emphasizing their potential in targeted and patient-friendly drug delivery system.

Keywords: *Mucoadhesion; Mucoadhesive polymers; Mucosal drug delivery; Controlled drug release; Bioavailability; Nanomucoadhesive systems*.

***CORRESPONDING AUTHOR**
Shek Basheera Bee

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INTRODUCTION

The term mucoadhesion has garnered significant attention in the pharmaceutical industry since the early 1980s [1] when Wisconsin University professor Joseph R. Robinson coined the term cohesion as a novel strategy to prolong the duration of drug residence on the ocular surface [2]. Pharmaceutical technology has seen a significant increase in interest due to the concept of cohesion [3]. The term "bioadhesion," which is primarily used to characterize the adhesion between polymers and soft tissue, describes any bond formed between natural and synthetic materials with a biological surface [4]. This idea started to be used in drug delivery systems in the 1980s. To increase the medication's bioavailability and promote local or systemic effects, sticky molecules are incorporated into pharmaceutical formulations that are meant to remain in close contact with the absorption tissue and release the drug close to the action site (4; 3, 2001) [5]

OVERVIEW OF MUCOSAL SURFACE

The wet surfaces that line the walls of different body cavities, including the gastrointestinal and respiratory tracts, are called mucous membranes, or mucosae Protecting against infectious organisms including bacteria, viruses, and fungus is one of the mucous membrane's primary roles. The vaginal mucosa produces a naturally occurring vaginal discharge to keep the vagina moist and self-clean [6].

MORPHOLOGY AN FUNCTIONS ASPECTS OF MUCOSA

Two forms of mucins-membrane-bound and secreted (soluble) biomacromolecules-coat the epithelial cells of the mucosal tissues, creating a fully hydrated viscoelastic gel layer (mucus). Peptide bonds and intramolecular cysteine–cysteine disulfide bridges bind the 500 kDa subunits that make up soluble mucins, which are high molecular weight glycoproteins (0.5–40 MDa) [7].

Mucus gel is a dynamic structure that is constantly reconstructed by the goblet cells' release of mucins. With a clearance duration that ranges from 5.0 to 7.7 minutes in the eye, 10 to 20 minutes in the respiratory system, and 4 to 6 hours in the gastrointestinal system, it has a comparatively brief lifespan . The mucus gel inhibits the diffusion of numerous medication

molecules and nanomedicines while simultaneously serving as a special and effective protection system [8].

FUNDAMENTAL MECHANISMS OF MUNCOADHESION

We still don't fully understand how some macromolecules adhere to the mucous tissue surface. In order to promote the dispersion of its chains within the mucus, the mucoadhesive must diffuse across the substrate to create tight contact and increase surface contact. There are forces of attraction and repulsion, and the attraction forces must be stronger for a mucoadhesive to work. Figure 3 illustrates the two steps that the adherence of mucoadhesive polymer into the mucin layer of mucosal tissue occurs in The presence of mucus in the mucosal membrane facilitates these activities Physical entanglement and secondary interactions, including hydrogen bonds, vander Waals forces, and electrical attractions, allow the polymer of the mucoadhesive formulation to penetrate the mucosal surface during the consolidation stage [9].

THEORITICAL APPROACHES OF MUCOADHESION

Many theories have been put out to explain the mechanisms underlying mucoadhesion, a complex process with an unclear chemical and physical basis. The electronic theory is predicated on the idea that biological and mucoadhesive materials have opposing electrical charges. Thus, the two materials transfer when they come into touch. electrons, causing a double electrical layer to form at the contact. The creation of attraction forces within this double layer is the ultimate outcome of such a process [10].

Adsorption hypothesis

This theory states that adhesion is caused by a variety of surface interactions between the mucus substrate and the sticky polymer, including primary and secondary bonding. According to the theory, adherence to tissue results from the combined action of one or more secondary forces, including hydrophobic bonding, hydrogen bonding, and van der Waal's forces

Wetting theory

This theory pertains to liquid systems that exhibit surface attraction in order to disperse over it. The contact angle is one measurement method that can be used to determine this affinity. According to the general norm, affinity increases with decreasing contact angle (Figure 4). For sufficient spread ability, the contact angle must be equal to or nearly equal to zero.The spread ability coefficient, SAB, can be calculated from the difference between the surface energies γB and γA and the interfacial energy γAB, as indicated in the equation given below This theory explains the importance of contact angle and reduction of surface and interfacial energies to achieve good amount of mucoadhesion.

$$SAB = \gamma B - \gamma A - \gamma A$$

Diffusion theory

It is thought that the adhesion force rises with the degree of penetration of the polymer chains This interpenetration depth of polymer and mucin chains can be estimated by following equation.

$$l = (tDb)^{1/2}$$

Where,

Db is the mucoadhesive material's diffusion coefficient in the mucus, and t is the contact time. The mucoadhesive bond is better the more structurally similar it is.

Fracture theory :

In research on the mechanical measurement of mucoadhesion, this idea is arguably the most frequently applied. In tests of resistance to rupture, this force, sm, is commonly computed as the ratio of the total surface area, A0, engaged in the adhesive contact and the maximal detachment force, Fm.

$$Sm = \frac{Fm}{Ao}$$

Mucoadhesive Materials

These hydrophilic groups also cause polymers to expand in water, exposing the greatest amount of sticky surfaces.

MUCOADHESIVE POLYMERS : AN OVERVIEW

A mucoadhesive polymer should have site-specificity, be non-toxic and non-irritating to the mucosal surface, and have a rapid rate of adhesion to the tissues it is applied to. Mucoadhesive polymers should be affordable, easily accessible, repeatable, and not break down while being stored

Three major categories can be used to classify polymers that stick to biological surfaces

1. Polymers that adhere through nonspecific, noncovalent interactions which are primarily electrostatic in nature
2. Polymers possessing hydrophilic functional groups that hydrogen bond with similar groups on biological substrates. Polymers that bind to specific receptor sites on the cell or mucus surface
1. The latter group of polymers comprises thiolated polymers and lectins. Lectins have been thoroughly investigated, particularly for drug-targeting applications, and can bind to carbohydrates on the surface of mucus or epithelial cells [11].

CATEGORIZATION OF MUCOADHESIVE POLYMER

Hydrophilic polymers, which frequently exhibit a strong capacity to adhere to mucosal membranes, are typically included in formulations to make dosage forms mucoadhesive. The chemical structure and functionality of several kinds of mucoadhesive polymers will be examined here [12].

- Anionic polymers

The capacity of carboxylic groups to establish hydrogen bonds with the oligosaccharide chains of mucins has frequently been linked. These liquid dosage forms can be injected into the eye to create a gel that adheres to the mucosal surfaces of the eyes and improves dosage form retention

Cationic Polymers

Chitosan and its derivatives' mucoadhesive qualities have been extensively used to create pharmaceutical formulations for oral, nasal, ocular, and Oro mucosal routes of delivery.

Non-Ionic Polymers

In general, non-ionic polymers function less well as mucoadhesive than polyelectrolytes and mucin are typically very weak and frequently not detectable using standard physicochemical methods.

Amphoteric Polymers

Few research have examined the mucoadhesive characteristics of polyampholytes, or polymers that have both cationic and anionic functional groups in their chains. Gelatine and N-carboxymethyl chitosan are the two polyampholytes most frequently utilized in mucoadhesive formulations.

Polymeric Thiomers

Polymers with side chains that contain functional groups that bear thiols are known as thiomers. This result was explained by the production of intermolecular disulfide connections [13].

POLYMERS UTILIZED IN MUCOADHESIVE FORMULATION

Water-soluble and water-insoluble mucoadhesive polymers stick to the mucin-epithelial surface to prolong contact time at the absorption site. The ideal mucoadhesive polymer should be affordable, stable over the course of its shelf life, nontoxic, non-irritating, and non-absorbable, and it should form a strong non-covalent connection with the surfaces of mucin-epithelial cells [14].

USE OF POLYMERS IN NEWER MDDS

Mucoadhesive polymers are frequently used to create unique drug delivery systems, such as gel, microspheres, beads, patches, etc., that can be administered orally, buccal, nasally, vaginally, etc. The prepared unidirectional buccal patches provided a maximum drug release within specified cohesion period, and this indicates a potential alternative drug delivery system for systemic delivery of carbamazepine [15].

FACTORS GOVERNING MUCOADHESION AND DRUG RELEASE

The mucoadhesive drug delivery systems are affected by polymer related factors, environmental factors, and physiological factors, which are the followings

Polymer Related Factors

- Molecular Weight
- Flexibility of Polymeric Chains
- Environmental Related
- Applied Strength
- Initial Contact Time

FUTURE PERSPECTIVES

1. Personalized Mucosal Therapies

Customized dosage forms to improve therapeutic outcomes and reduce side effects.

2. Nanotechnology and Biologics Integration

Targeted and controlled drug delivery for complex and chronic diseases.

3. Vaccine Delivery Applications

Improved mucosal immunity.

4. Telemedicine and Remote Monitoring Integration

Remote supervision of treatment by healthcare providers.

5. Smart and Enhanced Drug Delivery Devices

Real-time data collection and monitoring.

CONCLUSION

Mucoadhesive drug delivery systems have emerged as a promising and innovative approach to improve the therapeutic effectiveness of various drugs a result, they contribute to improved bioavailability, particularly for poorly soluble drugs and those that undergo extensive first-pass metabolism. Oral mucoadhesive formulations have gained considerable attention due to their ability to reduce dosing frequency. Furthermore, mucoadhesive systems have been successfully explored for multiple routes of administration, including buccal, nasal, ocular, and vaginal delivery, thereby expanding their therapeutic applications. Recent advancements focus on the design and validation of new techniques to evaluate mucoadhesive properties and optimize formulation strategies. Overall, a deeper understanding of mucoadhesion will facilitate the development of more effective, safer, and cost-efficient drug delivery systems for a wide range of therapeutic agents.

AUTHOR CONTRIBUTIONS

All authors are contributed equally.

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REFERENCES

1. Yadav V, Sipai A, Mamatha Y, Prasantha V. Transdermal drug delivery: a technical writeup. J Pharm Sci Innov. 2012;1(1):5-12.
2. Verma S, Kaul M, Rawat A, Saini S. An overview on buccal drug delivery system. Int J Pharm Sci Res. 2011;2(6):1303-1311.

3. Chickering DE III. Definitions, mechanisms, and theory of bioadhesion. In: Mathiowitz E, Chickering DE III, Lehr CM, editors. Bioadhesive Drug Delivery Systems: Fundamentals, Novel Approaches and Development. New York: Marcel Dekker; 1999. p. 1-10.
4. Favi PM, Yi S, Lenaghan SC, Xia L, Zhang M. Inspiration from the natural world: from bio-adhesives to bio-inspired adhesives. J Adhes Sci Technol. 2014;28(3-4):290-319. doi:10.1080/01694243.2012.691809.
5. Hägerström H, Edsman K, Strømme M. Low-frequency dielectric spectroscopy as a tool for studying the compatibility between pharmaceutical gels and mucous tissue. J Pharm Sci. 2003;92(9):1869-1877.
6. Peppas NA, Sahlin JJ. Hydrogels as mucoadhesive and bioadhesive materials: a review. Biomaterials. 1996;17(16):1553-1561.
7. Khanvilkar K, Donovan MD, Flanagan DR. Drug transfer through mucus. Adv Drug Deliv Rev. 2001;48(2-3):173-193. doi:10.1016/S0169-409X(01)00115-6.
8. Rao C. Evaluation of antiulcer activity of *Picrasma quassioides* Bennett aqueous extract in rodents. Vedic Res Int Phytomed. 2013;1:27-34.
9. Gindi S, Methra T, Chandu BR, Boyina R, Dasari V. Antiurolithiatic and in vitro antioxidant activity of leaves of *Ageratum conyzoides* in rats. World J Pharm Pharm Sci. 2013;2:636-649.
10. Nama S, Chandu BR, Awen BZ, Khagga M. Development and validation of a new RP-HPLC method for the determination of aprepitant in solid dosage forms. Trop J Pharm Res. 2011;10(4):489-495.
11. Kiranmai M, Renuka P, Brahmaiah B, Chandu BR. Vitamin D as a promising anticancer agent. Int J Res Pharm Chem. 2012;2(1):108-114.
12. Degapati RT. Novel approaches in transdermal drug delivery system. J Multidiscip Res. 2025;20-25.
13. Nanjwade BK, Bechra HM, Derkar GK, Manvi FV, Nanjwade VK. Dendrimers: emerging polymers for drug delivery systems. Eur J Pharm Sci. 2009;38(3):185-196.
14. Prasanthi G, Chandu BR, Kumar YP, Swarnalatha D, Gopinath C. Chemical pharmacology of khat leaves. J Glob Trends Pharm Sci. 2012;3(4):856-864.
15. Chaitanya GM, Sasi B, Kumar A, Rao CB, Rao BP, Jayakumar T. Prediction of fracture profile using digital image correlation. In: Proceedings of the Twelfth International Conference on Quality Control by Artificial Vision; 2015 Apr 30; Le Creusot, France. Bellingham (WA): SPIE; 2015. p. 281-288. doi:10.1117/12.2182911.