An analytical assessment on Mucoadhesive Buccal Drug Delivery System for improving patient convenience and compliance

Suresh Babu P*1, Marina Amarendra1, Subha V J2, Senthamarai S2

1Department of Pediatrics, Konaseema Institute of Medical Sciences Research Foundation, Amalapuram, Andhra Pradesh, India
2Department of Microbiology, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India

ABSTRACT

In recent years, the novel mucoadhesive buccal drug delivery system has been developed over the conventional and systemic dosage forms. To bypass drugs from the hepatic first-pass metabolism and it enhances the bioavailability of drug at the site of administration. Absorption of a drug through the buccal film/patch reduces the degradation. Some of the enzyme activity and pH variation in the gastrointestinal tract reduces the absorption and active drug loss. To overcome this problem, the buccal route is preferred. Polymers are used in this formulation to improve the drug release rate over an extended period, and also, the therapeutic plasma level of the drug can be rapidly achieved. Overall this narrative review explains mechanism and theories, method of preparation, factors affecting mucoadhesion, advantages and limitations, applications, components used in the formulation, characterization and evaluation methods. Since the cytoplasm and intercellular spaces are hydrophilic. Lipophilic drugs have a low solubility in this environment. However, the cell membrane is rather lipophilic; it tends to difficulty permeating the hydrophilic solute through the cell membrane because of a low partition coefficient. Therefore, the cytoplasm and intercellular spaces act as a major barrier to penetration of lipophilic compounds and the cell membrane poses as an extensive transport barrier for hydrophilic compounds. Since the oral epithelial is stratified, the permeation of solute may involve these combination routes so that the route is more predictable.

INTRODUCTION

Over the past few years, novel in drug formulations and advanced routes of administration have been developed. These advanced drug formulations enhance drug transport across tissues. The innovative formulation improves patient adherence to the therapeutic agent and improves pharmacologic response (Mahajan et al., 2013). The administration of a drug by transmucosal route (i.e., the mucosal linings of the nasal, rectal, vaginal, ocular, and oral cavity). Especially, the mucoadhesive buccal drug delivery system is an ideal formulation compared to the other routes. It enhances sustained, controlled release drugs at a targeted...
site for an extended period, and relatively being painless (Shinkar et al., 2012). Additionally, buccal drug delivery has more patient acceptability than other non-oral transdermal routes of drug administration. It directly enters into the systemic circulation through the internal jugular vein. Controls acid hydrolysis in the gastrointestinal tract (GIT) and avoids drugs from the hepatic first-pass metabolism, hence leads to high bioavailability. However, fast cellular recovery of the buccal mucosa is another advantage of this route (Reddy et al., 2011).

Mucoadhesive drug delivery systems can be delivered by various routes (Singh et al., 2017)

1. Buccal delivery system
2. Oral delivery system
3. Rectal /Vaginal delivery system
4. Nasal delivery system
5. Ocular delivery system

Buccal delivery system
The buccal delivery system is similar to transdermal drug delivery systems (TDDS). Example of buccal delivery is buccal patches, films. Which consists of impermeable backing membrane and reservoir layer from which the drug is released in a controlled manner? It can be prepared either by solvent casting or direct milling. An impermeable backing membrane may also be applied to control the release of the drug, prevent drug loss, and minimize disintegration. Suitable bioadhesive buccal patches with desired permeability buccal delivery show good absorption and bioavailability compared to the oral solution. Buccal patches and films of sustained-release drugs bypass the extensive hepatic first-pass metabolism along with increased bioavailability (Sonawane et al., 2017).

Oral delivery system
The oral delivery system has several advantages for the administration of macromolecules (i.e. proteins). It also avoids pain and discomfort related to injections as well as infections caused by the use of needles. Oral mucosa is highly permeable, rapid absorption convenient and shows adequate bioavailability of drugs. Delivery of the drug across the oral mucosa can be classified into three different types. They are,

1. Sublingual drug delivery: Administration of the drug through the mucosal membrane of the dorsal surface of the tongue and lining the floor of the mouth.
2. Buccal drug delivery: The administration of the drug through the buccal mucosa, mainly consists of the lining of the cheeks. In the human body oral cavity is the anterior part of the digestive system. It is also called a "buccal cavity".
3. Local drug delivery: Administration of the drug through all areas other than these two regions. These, site anatomically varies in their rate of drug delivery, permeability to drugs, and the ability to maintain a drug for a prolonged period.

Rectal /vaginal drug delivery
New rectal /vaginal drug delivery has been developed to improve the pharmacological effects of various classes of drugs like anti-inflammatory, analgesic and antiseptic drugs (Mansuri et al., 2016). The drugs are given by rectal which do not undergo the first-pass metabolism in the GIT and the liver. It is an approved delivery system for infants, children, and unconscious patients. A suppository is a good example of the vaginal delivery system; it contains medicated solid dosage form which melts at body temperature. However, suppositories often give the patients a feeling of discomfort, alien during insertion and refusal. The leakage of suppositories from the vagina gives itchy feelings to the patients.

Nasal delivery system
The nasal mucosa has a common administration site for systemic drug delivery an alternative route to parenteral drug delivery due to its self-medication and virtually painless. In modern pharmaceutics, the nose has been considered mainly as a route for local drug delivery particularly important in the management of difficult situations such as severe nausea and vomiting (Sangeetha et al., 2010). Nowadays, the nasal cavity is being particularly used for therapeutic agents like peptides and proteins for immunization purposes. Nasal drug delivery is essential for medications used in emergency medical situations.

Ocular delivery system
The mucoadhesive concept is now considered as a new approach to optimizing the ocular dosage form. There are so many disorders of the eye that can be treated by the topical application of the drug, and this administration is well accepted. Viscous semi-solid preparations, i.e. gel and ointments, provide sustained contact with the eye, but they lead sticky sensation, blurred vision, irritation and blinking due to discomfort.

Mechanism of mucoadhesion
The contact between the surface and pressure-sensitive adhesive substance is called adhesion; otherwise, it can be defined as two surfaces are attached because of their interlocking action or valence interfacial force or else both. In this bio adhesion is the adhesion of natural or synthetic material on biological membrane but in mucoadhesion, adhesion of materials to an epithelial membrane takes place (Reineke et al., 2013).

Mucoadhesion occurs in two stages. They are,

**Stage-1 (contact stage)**

It is characterized by wetting, spreading, and swelling of the bioadhesive membrane, it creates close contact between a membrane and bioadhesive material. In some cases of vaginal in Figure 1 or ocular formulations, the delivery system is established mechanically over the membrane (Rajaram and Laxman, 2017).

**Stage-2 (consolidation stage)**

It is characterized by penetration of the mucoadhesive/bioadhesive between two surfaces of the mucous membrane due to hydrogen bonding and hydrophobic interactions, Vander walls forces or electrostatic attractions. Consolidation step is explained by two theories:

**Diffusion theory**

It is a chemical as well as mechanical interaction. Here, mucus glycol protein reacts with the mucoadhesive moiety by interpenetrating their chains and forming secondary bonds.

**Dehydration theory**

Mucus and adhesive material are after contact with each other; they undergo dehydration until osmotic pressure reaches equilibrium. A mixture of mucus and material is obtained in the form of a gel (Verma, 2018).

Figure 1: Stages of Mucoadhesion

Theories of mucoadhesion

Figure 2: Diffusion interlocking theory

To describe the mechanism of mucoadhesion several theories have been proposed, they are (Mohanty et al., 2018),

1. Wetting theory
2. Adsorption theory
3. Electronic theory
4. Fracture theory
5. Mechanical theory
6. Diffusion interlocking theory

**Wetting theory**

This theory applicable to the liquid system. It explains the ability to spreadability of the polymer. Is having an affinity to the surface to spread over it. The affinity can be determined by using different techniques such as the contact angle. Affinity is indirectly proportional to the contact angle; it means, lower the contact angle greater the affinity (Caon and Jin, 2015).

**Adsorption theory**

In this mucoadhesive device, different types of chemical bonding play an important role in the adhesion interaction, i.e. Hydrogen bonds, Vander walls, and electrostatic attraction (Dodou et al., 2005).

**Electronic theory**

In this theory, the electron transfer between mucoadhesive and biological membrane leading to the formation of a double electronic layer at the interface of the mucoadhesive and membrane due to differences in their electronic structure. This results in attractive forces with the double layer and determines the strength of mucoadhesive (Ahagon and Gent, 1975).

**The fracture theory**
Table 1: The different components used in the Mucoadhesive buccal drug delivery system are as follows

<table>
<thead>
<tr>
<th>Sl.no.</th>
<th>Components</th>
<th>Example</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Polymers (Smart, 2005)</td>
<td>Sodium carboxymethylcellulose, methylcellulose, Hydroxyethylcellulose, hydroxypropyl cellulose, polyvinyl pyrrolidone, polyvinyl alcohol, etc.</td>
<td>Polymers control the rate of release of drug from the buccal mucoadhesive film.</td>
</tr>
<tr>
<td>2</td>
<td>Diluents</td>
<td>Lactose DC, microcrystalline starch and starch</td>
<td>To enhance the aqueous solubility improves its flavoring characteristics,</td>
</tr>
<tr>
<td>3</td>
<td>Backing layer</td>
<td>Ethylcellulose, cellulose acetate, etc.</td>
<td>It should provide good flexibility and high tensile strength, and stabilizer</td>
</tr>
<tr>
<td>4</td>
<td>Penetration enhancer</td>
<td>Cyano acrylate, cyclodextrin cetylpyridium, etc.</td>
<td>Substances that help to enhance drug permeation through a buccal epithelium and absorption</td>
</tr>
<tr>
<td>5</td>
<td>Plasticizer (Averineni et al., 2009)</td>
<td>PEG-100,400, propylene glycol glycerol, castor oil, etc.</td>
<td>The substance which is used to improves the softness and flexibility of the thin buccal film</td>
</tr>
<tr>
<td>6</td>
<td>Flavouring agents</td>
<td>Clove oil, menthol, peppermint oil, vanillin, etc.</td>
<td>To enhance the therapeutic effect.</td>
</tr>
<tr>
<td>7</td>
<td>Sweetening agents</td>
<td>Mannitol, sorbitol, glycerol, sucrose, aspartame, etc.</td>
<td>They are used to reduce the bitter taste of the formulation and increase the palatability of the therapeutic agents</td>
</tr>
<tr>
<td>8</td>
<td>Drug</td>
<td>Antibiotic (ofloxacin, cephalexin), antifungal (Fluconazole, clotrimazole) NSAIDS, etc.</td>
<td>To exist therapeutic effectiveness at a specific site.</td>
</tr>
</tbody>
</table>

This fraction theory is necessary to explain, the force required to separate bonds of adhesion between two surfaces (Gilhotra et al., 2014).

**Diffusion interlocking theory**

This theory explains mucoadhesive polymer chain diffuses into the mucous layer due to the breaking of the glycoprotein chain network Figure 2. This diffusion is depending on diffusion co-efficient and time-dependent also concentration-dependent (Sharma et al., 2012).

**Methods of preparation of mucoadhesive drug delivery**

**Solvent casting**

The solvent casting method is the widely preferred method for the preparation of buccal film/patches (Nagpal et al., 2016). In this method, all film/patch excipients, including the polymer along with drug dispersed in an organic sol-
vent (Reena, 2018). Above solvent mixture kept for overnight, and then triturated until to get a homogenous system then add glycerine and forms a gel in a Table 1. To prevent entrapment of the air bubbles inside the patch/film, the entire gel was subjected to vacuum desiccators to remove bubbles. Then the gel was transferred into glass molds lined with an aluminium foil and allows gel casting for a period of 24 hr. The dried films are obtained, then remove from the glass molds, then patches are die-cut into the desired size and geometry. The patches were packed in aluminium foil and stored at room temperature then maintained the integrity and elasticity of the films (Ahuja et al., 1997).

**Direct milling**

Drugs and excipients are mixed by kneading, usually without using any liquids. After the mixing process, the mixture is rolled on a release liner until the desired thickness is obtained. The backing material is then laminated. To characterize the film solvent-free process is selected because there is no possibility of residual solvents and no other solvent related health issue (Khan et al., 2014).

**Hot-melt extrusion of films**

In the hot-melt extrusion method, shaping a polymer into a film through the heating process. A blend of all active pharmaceutical ingredients in a dry state. Then it is filled in the hopper, conveyor, mixer then subjected to the heating process. In the extruder, the mixture gets molten and form a molten state. The molten mass then used to cast the film. Casting and drying is a critical process in this method. This method has many advantages like it can be carried out at a lower temperature and less time consumption. Continuous operation possible, reducing the wastage, improves product quality (Venkatalakshmi et al., 2012).

**Evaluation of mucoadhesive buccal films**

**Surface pH**

For determination of the surface pH, the buccal patch is allowed to swell for 2 hr by keeping them in contact with 1 ml of distilled water at room temperature. The pH was recorded by using pH meter, placing the electrode in contact with the surface of the patch and allows equilibrating for 2 minutes (Yam-sani et al., 2007).

**Thickness measurement**

The thickness of each film/patches was determined using an electronic digital micrometre. Usually, thickness measured at different locations (i.e. centre and four corners) (Smart, 2005).

**Drug content**

The prepared film/patch was analyzed for drug content. Five mucoadhesive films were taken and the contents are dissolved in suitable solvent phosphate buffer 6.8 in 100 ml volumetric flask. Shake well, the drug content was determined by measuring the absorbance at respective wavelength using UV-spectrophotometer (Averineni et al., 2009).

**Swelling studies**

The films were cut into 3*2 cm2 pieces. Then calculate the primary weight of the film (W1), the swelling properties of patch/films was determined by placing films in phosphate buffer solution (pH 6.8) at 37°C. At specified time intervals of 5 min, then films were removed from the solution and the swollen films were weighed (W2) and the swelling ratio was calculated (Reddy et al., 2013).

**Folding endurance**

The folding endurance of the film/patches was determined by continuous folding a patch at the same place until it breaks or is folded up to 250 times without breaking (Madhavi et al., 2013).

**Mucoadhesive strength**

Mucoadhesion studies are performed by using the physical balance. The porcine buccal mucosa membrane was collected from slaughterhouse excised and washed, then tied tightly to the upper part of glass vials, which contains PBS (pH 6.8) to keep the mucosal surface moisten. The patch was then fixed with a little moist on to the surface of lower rubber closure hanging from then brought in contact with the mucosa. The balance is kept in this position for 5 min and then gradually weigh until the patch separated from the mucosal membrane surface (Castán et al., 2015).

**Tensile strength and percentage elongation to break**

Tensile strength (TS) is the maximum stress applied to a specific part of patch/films without tearing. Elongation to break (EB) is the maximum deformation of patch/films length without tearing. TS and EB% were calculated by using the following equations (Salehi and Boddohi, 2017).

**Morphological Characterization**

**Scanning electron microscope**

The surface morphology of the selected films was studied by using a scanning electron microscope. after the film was gold-sputtered under vacuum visualize the film at an acceleration voltage of 80kV (Obaidat et al., 2010).

**Differential scanning calorimeter**

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This study was carried out to identify the arrangement of crystal on a pure drug, excipients, polymer, physical mixtures, and selected drug-loaded films. Accurately weighed samples were placed in aluminium pan and scans were performed under nitrogen stream (Anil and Preethi, 2018).

**In-vitro Release Study**

The *in-vitro* drug release study was performed by using a Franz diffusion cell, using commercially available dialysis membrane (Manivannan et al., 2008). The receptor compartment was filled with phosphate buffer solution (pH 6.8.) The patches were placed on the dialysis membrane is fitted between the donor and receptor compartments of the cell. The drug release was carried out at 37±0.5°C, with continuous stirring using a magnetic stirrer (Nautiyal, 2013). The sample was withdrawn from the receptor medium at specific intervals. The amount of drug released into the receptor medium was determined by using UV-visible spectrophotometer at a specific wavelength against a blank (El-Kamel et al., 2007).

**Ex-vivo permeation study**

The *ex-vivo* permeation studies of buccal films were carried out using an excised layer of the porcine buccal mucosa (Adhikari et al., 2010). The study was carried out using the modified Franz diffusion cell. A piece of the patch was placed in intimate contact between excised porcine buccal mucosa and the top of the assembly was closed with aluminium foil. The receptor compartment was filled with phosphate buffer then stirred with a magnetic stirrer. The temperature of the instrument was maintained at 37±10°C. The samples were withdrawn at a specific time of interval, then analyzed using a UV spectrophotometer at the respective wavelength (Labib et al., 2014).

**CONCLUSIONS**

Now, innovative drug delivery systems designed to improve patient compliance and convenience. Therefore, massive work is going on to develop mucoadhesive buccal dosage forms to satisfy patient demands than conventional dosage forms. Buccal mucosa delivery improved a convenient way of dosing medication and controlled the release of drugs for a prolonged period. This formulation is economy, high patient compliance, and ease of administration. Mucoadhesive polymers improve bioavailability and residence time of the active agent. Mucoadhesion buccal film provides satisfactory treatment than other drug delivery systems.

**Conflict of Interest**

The authors declare that they have no conflict of interest for this study.

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