

## Comprehensive Review on Mucoadhesive Gastro Retentive Tablets of Gliclazide by Using Mucoadhesive Polymers

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### Abstract:

Mucoadhesive and gastro-retentive drug delivery systems (MDDS and GRDDS) enhance the bioavailability, efficacy, and patient compliance of poorly soluble, short half-life antidiabetic drugs such as glimepiride and gliclazide. Formulations using polymers like sodium alginate, chitosan, HPMC, xanthan gum, and Carbopol demonstrated prolonged drug release, strong mucoadhesion, gastroretention, and stability. Solubility and bioavailability were improved through techniques such as solid dispersions,  $\beta$ -cyclodextrin complexes, and alginate-based systems. Clinical studies confirmed safety, effective glycemic control, reduced hypoglycemic risk, and improved compliance, highlighting the importance of formulation design and polymer selection in developing effective oral drug delivery systems.

**Key words:** Mucoadhesive, gastro-retentive, gliclazide, antidiabetic.

- Transdermal Drug Delivery Systems
- Vesicular Drug Delivery Systems
- Nanoparticle-Based Drug Delivery Systems
- Microspheres and Microcapsules
- Implantable Drug Delivery Systems
- Ocular Drug Delivery Systems
- Nasal Drug Delivery Systems
- Buccal and Sublingual Drug Delivery Systems
- Colon-Targeted Drug Delivery Systems
- In-Situ Gelling Drug Delivery Systems

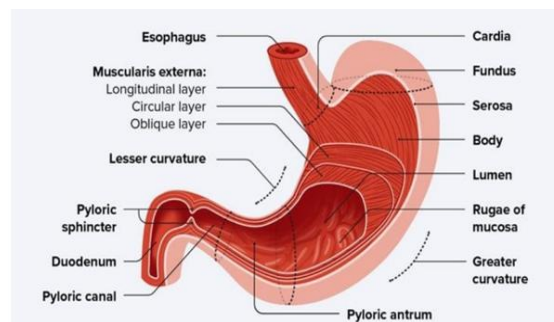


Figure 1: Stomach Anatomy

### I. INTRODUCTION:

#### 1.1 NOVEL DRUG DELIVERY SYSTEM (NDDS)

It is an advanced pharmaceutical formulation or technology designed to deliver a drug to the specific site of action at a controlled rate and for a predetermined period of time, with the aim of enhancing therapeutic efficacy, improving bioavailability, reducing side effects, and increasing patient compliance when compared to conventional dosage forms.<sup>[1]</sup>

#### 1.2 TYPES:

- Controlled Drug Delivery Systems
- Targeted Drug Delivery Systems
- Gastro-Retentive Drug Delivery Systems (GRDDS)
- Mucoadhesive Drug Delivery Systems

### II. GASTRORETENTIVE DRUG DELIVERY SYSTEMS:

Gastroretentive Drug Delivery Systems (GRDDS) are advanced oral drug delivery approaches designed to prolong the residence time of drugs in the stomach, thereby enhancing bioavailability and therapeutic efficacy. These systems are particularly beneficial for drugs that are absorbed mainly in the stomach or upper small intestine, have a narrow absorption window, or show poor intestinal absorption. By increasing gastric retention, GRDDS enable sustained and controlled drug release, reduce dosing frequency, and improve patient compliance compared to conventional oral dosage forms. GRDDS are formulated to withstand the acidic gastric environment while ensuring

predictable drug release. Based on their mechanism of gastric retention, they are classified into floating systems that remain buoyant in gastric fluids, bioadhesive systems that adhere to the gastric mucosa, swellable systems that expand in gastric conditions to prevent premature emptying, and multiparticulate systems such as microspheres and beads that provide uniform drug release and dosing flexibility.<sup>[4]</sup>

### 2.1 Advantages of gastroretentive drug delivery system

- ❖ It increases patient compliance by reducing dosing frequency
- ❖ Buoyancy increases gastric residence time
- ❖ Better therapeutic effect of short half-life drugs
- ❖ Site specific drug delivery to stomach can be achieved
- ❖ Gastric irritation can be avoided by designing sustained release.

### 2.2 Disadvantages of gastroretentive drug delivery system

- ❖ Floating systems has limitation, that they require high level of fluids in stomach for floating and working efficiently.
- ❖ Drugs having stability problem in high acidic environment.
- ❖ Bio/mucoadhesives systems have problem of high turnover rate of mucus layer, thick mucus layer & soluble mucus related limitations.

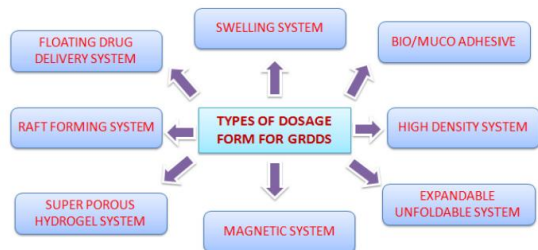


Figure 2: Types of Dosage form for GRDDS

### III. MUCOADHESIVE DRUG DELIVERY SYSTEM :

Mucoadhesive drug delivery system uses bioadhesive polymers that become adhesive upon hydration.

1. These systems help retain the drug at a specific site in the body for a prolonged period.

2. Mucoadhesion refers to the adhesion of a material to the mucosal layer of biological tissue.
3. Both natural and synthetic polymers are used to achieve mucoadhesion.
4. The system ensures intimate contact between polymer and target tissue drug release control.

**Mucoadhesive drug delivery systems** are designed to adhere to mucosal surfaces such as the gastrointestinal tract, oral cavity, nasal cavity, and vaginal cavity, thereby increasing the residence time of drugs at the site of absorption. By adhering to mucosal tissues, protect drugs from gastrointestinal degradation and reduce first-pass metabolism.

Drugs absorbed directly through the mucosal lining bypass the digestive system and hepatic metabolism, improving systemic drug availability. The physicochemical properties of mucus, along with polymer hydration and moisture content, play a critical role in mucoadhesive interactions.

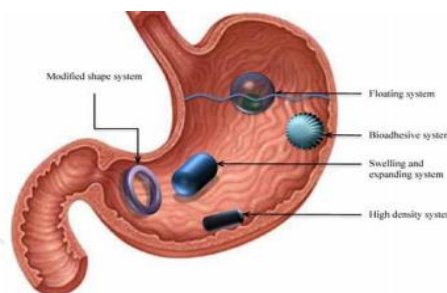


Figure 4: Mucoadhesive drug delivery system

Biopolymers are particularly attractive for mucoadhesive systems because of their biocompatibility, biodegradability, and formulation flexibility. Recent advances in biopolymer research, formulation technologies, and targeted drug release strategies have significantly improved medication efficacy and patient compliance.

### IV. DIABETES MELLITUS:<sup>[5]</sup>

It is a group of metabolic disorders characterized by high blood glucose levels due to defects in insulin secretion, insulin action, or both. Type 1 Diabetes Mellitus (T1DM) occurs due to autoimmune destruction of pancreatic  $\beta$ -cells by CD4 and CD8 T-cells and macrophages, leading to absolute insulin deficiency. Lifelong insulin therapy is required to prevent ketoacidosis, coma, and death. Type 2 Diabetes Mellitus (T2DM) is a heterogeneous metabolic disorder caused by defects in insulin secretion and insulin sensitivity. It involves  $\beta$ -cell dysfunction, including impaired insulin release,

qualitative and quantitative insulin abnormalities, and progressive  $\beta$ -cell loss. Gestational Diabetes Mellitus (GDM) is glucose intolerance first recognized during pregnancy, usually in the second

or third trimester. It affects about 4% of pregnancies, and 30–50% of affected women may later develop Type 2 diabetes.

## V. MATERIALS & METHODS:

Table no:1 Drug, Polymers, Excipients:

| S.No. | Drug                        | Manufacture            |
|-------|-----------------------------|------------------------|
| 1.    | Gliclazide                  | Madras Pharmaceuticals |
| 2.    | Chitosan                    | Yarrow chem            |
| 3.    | Xanthan gum                 | Himedia lab.Pvt.Ltd    |
| 4.    | Moringa gum                 | Prepared in Lab.       |
| 5.    | Micro crystalline cellulose | yarrowchem             |
| 6.    | Magnesium stearate          | Loba Chem.             |
| 7.    | Talc                        | Loba Chem.             |
| 8.    | Hydrochloric acid           | Loba Chem.             |

## VI. METHODOLOGY:

### 6.1 PREFORMULATION STUDIES:

A comprehensive preformulation study helps in characterizing the physico-chemical properties of the drug molecule. It provides the foundation for development of a robust dosage form that can sustain the rigors of processing and shelf life. Efforts spent on preformulation provide cost savings in the long run, by reducing challenges during formulation development.

### 6.2 MELTING POINT

Melting point of drug sample was determined by taking small quantity of drug in a capillary tube sealed at one end and was placed in digital melting point apparatus and temperature range at which the drug melts was noted. Melting point is a key preformulation parameter used to assess drug purity, stability, solubility, and formulation behavior. A sharp melting point indicates purity, while deviations suggest impurities or degradation. Low melting point drugs may show physical instability during processing and storage. As melting point is inversely related to solubility, high melting point drugs often have poor dissolution and bioavailability. It also helps in selecting suitable manufacturing conditions, identifying polymorphism, and detecting possible drug–excipient incompatibilities.

### 6.3 DETERMINATION OF $\lambda_{MAX}$ :

The determination of  $\lambda_{max}$  identifies the wavelength at which a drug shows maximum absorbance in UV–Visible spectrophotometry. A standard drug solution is scanned between 200–400 nm, and the wavelength with the highest absorbance peak is recorded as  $\lambda_{max}$ . This wavelength is chosen for further quantitative analysis because the drug obeys Beer–Lambert’s law most accurately at  $\lambda_{max}$ , giving maximum sensitivity and precision. Once determined,  $\lambda_{max}$  is used for preparing calibration curves and for drug content and dissolution studies.<sup>[6]</sup>

### 6.4 PREPARATION OF CALIBRATION CURVE IN 0.1N HCL :

A 0.1N HCl buffer (pH 1.2) was prepared and used to make a Gliclazide stock solution of 1000  $\mu\text{g/mL}$ . From this, a 20  $\mu\text{g/mL}$  working solution and further dilutions (4–20  $\mu\text{g/mL}$ ) were prepared. The  $\lambda_{max}$  of Gliclazide was found to be 229 nm using a UV–Visible spectrophotometer. Absorbance of each dilution was measured at this wavelength, and a calibration curve of absorbance versus concentration showed a linear relationship, confirming adherence to Beer–Lambert’s law and the suitability of the method for estimating Gliclazide.

### 6.5 COMPATIBILITY STUDIES OF GLICLAZIDE AND POLYMERS:

• **FTIR studies:**

FTIR spectra help to confirm the identity of drug and to detect the interaction of the drug with the carriers. IR spectroscopy of pure drug and physical mixture of drug with polymers was carried out using FTIR to check the compatibility between drug and polymers. The IR spectra of drug with polymers were compared with the standard IR spectrum of the pure drug.

**6.6 FORMULATION OF MUCOADHESIVE TABLETS:**

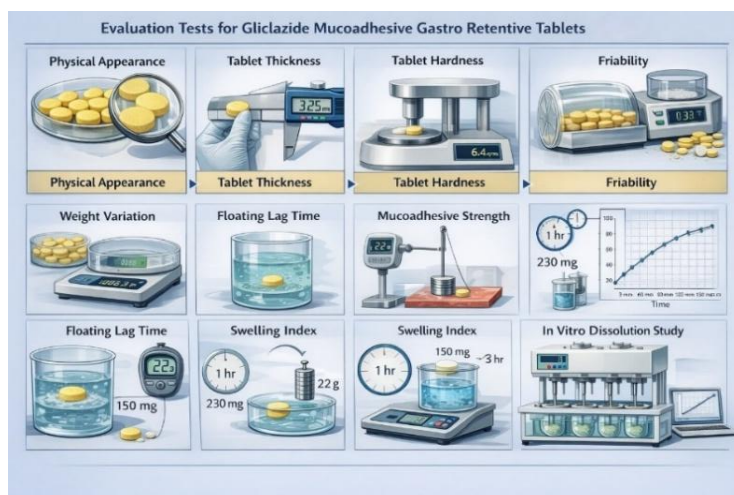
• **Screening of polymers and excipients:**

Preliminary formulations were designed by different natural polymer for screening of mucoadhesive system. Based on the results obtained, further experiments were designed using various natural polymers to develop optimized formula.

**VII. EVALUATION PARAMETERS:**

**7.1 Precompressional parameters:<sup>[7]</sup>**

1. Bulk density
2. Tapped density
3. Angle of repose
4. Hasusner's ratio
5. Carr's consolidation index



**Figure 5 : Evaluation Parameters**

**1) Bulk density:**

It is the ratio of total mass of powder to the bulk volume of powder. Accurately weighed batch (F1 –F10) powder was placed in 10 mL graduated measuring cylinder. Initial volume was observed. The  $D_b$  and was calculated in gm using following formulae,

$$D_b = M/V_b$$

**2) Tapped density:**

Accurately weighed batch (F1 –F10) powder was placed in 10 mL graduated measuring cylinder. The cylinder was tapped initially 100 times from a distance of 14 + 2 mm. The tapped volume was measured to the nearest graduated unit. Again the tap volume was measured to the nearest graduated unit. The  $D_t$  were calculated in gm using following formulae,

$$D_t = M/V_t$$

**3) Angle of repose:**

Good flow properties are ideal for the development of any pharmaceutical tablets, capsule or powder formulations.

**4) Hasusner's ratio:**

Hasusner's ratio carried out by tapped density divided bulk density.

$$\text{Hasusner's ratio} = \frac{\text{Tapped density}}{\text{Bulk density}}$$

**5) Carr's consolidation index:**

Carr's developed an indirect method of measuring powder flow from bulk densities. The % compressibility of the powder was direct measure of the potential powder arch or bridge strength and stability. Carr's index of each formulation was calculated using the given formula.

$$\text{Carr's index (\%)} = [(D_t - D_b) \times 100] / D_t$$

**7.2 Post compression parameters:<sup>[8]</sup>**

**1) Appearance:**

The tablets were checked for presence of cracks, pinholes etc. There should be uniformity in the color and the dimensions of the tablets.

2) **Hardness:**

This test is used to check the hardness of the tablet, which may undergo chipping or breakage during storage, transportation, and handling. In this, three tablets were selected randomly and the hardness of each tablet was measured with Monsanto hardness tester. The hardness is usually measured in terms of kg/cm<sup>2</sup>.

3) **Thickness:**

Thickness of tablet was important for uniformity of the tablet size. In this three tablets were selected randomly and the hardness of each tablet was measured with using screw gauze.

4) **Friability test:**

Friability test was carried out to evaluate the hardness and stability instantly. In roche friabilator, 10 tablets were weighed ( $W_0$ ) initially and put in a tumbling and rotating apparatus drum. Then they were subjected for completion of 4 min or 100 rpm, the tablets were again weighed. The % loss in weight or friability (F) was calculated by the formula given below.

$$\% \text{ friability} = \frac{\text{weight}_{\text{initial}} - \text{weight}_{\text{final}}}{\text{weight}_{\text{initial}}} \times 100$$

5) **Weight variation:**

This test was performed to maintain the uniformity of weight of each tablet, which should be in the prescribed range. This was done by weighing 10 tablets at random and average weight was calculated. Not more than two of individual weight deviates from the average weight. The weight data from the tablets were analyzed for sample mean and percent deviation.

$$PD = \frac{W_{\text{avg}} - W_{\text{ind}}}{W_{\text{avg}}} \times 100$$

6) **Uniformity of drug content:<sup>[9]</sup>**

The content uniformity was mandatory for tablets. This test was performed by taking five tablets were selected randomly, weighed and powdered. A tablet triturate equivalent to 40 mg of drug weighed accurately, dissolved in 10 mL of methanol then final volume made up to 100 mL by using pH 1.2 buffer. Further dilutions were done suitably and absorbance was measured at 229nm using UV spectrophotometer.

7) **Swelling index:<sup>[10]</sup>**

One tablet from each batch was weighed and placed in a Petri plate containing 25 mL of pH 1.2 buffer solution. After each 2 hrs interval the tablet was removed from plate, removes excess of buffer by using filter paper and weighed again up to 24 hrs. The swelling index was calculated using following formula.

$$\text{Swelling index (S.I)} = \frac{W_t - W_0}{W_0} \times 100$$

8) **In vitrodissolution studies:<sup>[10]</sup>**

Dissolution tests were performed in USP dissolution eight dissolution apparatus II (paddles) at 37±0.5°C. The baskets were rotated at a speed of 50 rpm. The test was performed in 37±0.5°C with a rotation speed of 50 rpm using 900 mL of 0.1 N HCl, pH 1.2, as a dissolution medium. According to the sampling plan, samples of 5 mL were withdrawn till 24 hrs and immediately replaced with an equal volume of the respective dissolution medium maintained at 37±0.5°C. Test samples were filtered through Whatman filter paper for Gliclazide at 229 nm using a blank solution as reference with a UV-VIS double-beam spectrophotometer

9) **Release kinetics:**

The results of *in vitro* release profiles obtained for all the HBS formulations were fitted into four models of data treatment as follows:

1. Cumulative percent drug released versus time (zero-order kinetic model).
2. Log cumulative percent drug remaining versus time. (First-order kinetic model).
3. Cumulative percent drug released versus square root of time. (Higuchi's model).
4. Log cumulative percent drug released versus log time (Korsmeyer-Peppas equation).

**1. Zero Order Kinetics:** A zero-order release would be predicted by the following equation.

$$A_t = A_0 - K_0t$$

**2. First Order Kinetics:** A first-order release would be predicted by the following equation

$$\text{Log } C = \text{Log } C_0 - 303.2Kt$$

**3. Higuchi's Model:**

Drug released from the matrix devices by diffusion has been described by following Higuchi's classical diffusion equation.

$$Q = \frac{D_e(2A - Ec_s)Cst_{1/2}}{\tau}$$

**4. Korsmeyer and Peppas Model:**

The release rates from controlled release polymeric matrices can be described by the equation (10) proposed by korsmeyer et al.

$$Q = K_1t^n$$

#### 10) *In vitro* mucoadhesive strength:

The mucoadhesive strength of tablets was evaluated using fresh sheep stomach mucosa as the model membrane. The mucosa was collected within 2–3 hours of slaughter, washed with distilled water, and mounted on a locally fabricated mucoadhesion apparatus. The tablet was attached to the mucosa, and the weight required to detach the tablet was recorded as the mucoadhesive strength. Each formulation was tested three times, and the mean value was used. After every test, the tissue was washed with phosphate buffer and allowed to rest for 5 minutes before testing the next tablet to ensure reliable results.<sup>[10]</sup>

#### VIII. STABILITY STUDIES:

Accelerated stability study was carried out as per the ICH guidelines. Selected formulations were subjected to determine its shelf life i.e. stability study by using accelerated stability chamber, according to the WHO guidelines. The tablets were stored in the stability chamber under temperature  $40 \pm 2^{\circ}\text{C}$  and  $75 \pm 5\%$  RH (relative humidity) for 90 days. After the specified period the tablets are subjected to physical appearance, drug content and dissolution study.

#### IX. CONCLUSION:

In summary, the development of mucoadhesive gastro-retentive tablets of Gliclazide represents a promising approach to **enhance patient compliance and therapeutic outcomes**. This delivery system effectively bypasses the limitations of conventional oral dosage forms by ensuring the drug remains in the "absorption window" of the upper gastrointestinal tract for an extended duration.

#### REFERENCE:

- [1]. Chien, Y. W. Novel Drug Delivery Systems. Marcel Dekker Inc., New York, 1992.
- [2]. Vyas, S. P., Khar, R. K. Targeted and Controlled Drug Delivery: Novel Carrier Systems. CBS Publishers & Distributors, New Delhi, 2002.
- [3]. Brahmanekar, D. M., Jaiswal, S. B. Biopharmaceutics and Pharmacokinetics – A Treatise. Vallabh Prakashan, New Delhi, 2015
- [4]. ANKUSH ML, ROHAN GA, VAIBHAV GA, VINAYAK AK, NANDKISHOR BD, SWATI PD. Formulation and Evaluation of Gastroretentive Drug Delivery System. GSC ADVANCED RESEARCH AND REVIEWS Учредители: GSC Online Press. 2025;22(1):182-94.
- [5]. Nayak, A. K., & Pal, D. (2017). Tamarind seed polysaccharide: an emerging excipient for pharmaceutical use. Indian Journal of Pharmaceutical Education and Research, 51(2s), s136–s146. <https://doi.org/10.5530/ijper.51.2s.60>
- [6]. Beckett, A.H. & Stenlake, J.B. Practical Pharmaceutical Chemistry, 4th Ed., CBS Publishers, 2005.
- [7]. Martin, J. Swarbrick and A. Cammarata. In: Physical Pharmacy, 4th edition, Philadelphia. 335-38:431-32. (2000).
- [8]. Lachman.L, Liberman, H.A. and Kanig, J.L. The Theory and Practice of Industrial Pharmacy, Varghese Publishing House, Mumbai, 3rd Edition. 1991: 297-303.
- [9]. Pandit V, Sarasija S, Joshi H. Gastroretentive drug delivery system of amoxicillin: formulation and in vitro evaluation. International Journal of Pharma and Bio Sciences. 2010; 1 (2): 13-23.
- [10]. Ingle US, Bankar VH, Gaikwad PD, Pawar SP. Solubility enhancement of oral hypoglycemic agent by solid Dispersion technique. International Journal of applied biology and pharmaceutical technology. 2011; 2 (2): 301-06.
- [11]. Senthil V, Kumar R, Lavanya K, Rathi D, venkatesh N, Ganesh GN, Jawahar K, et al. In vitro and In vivo evaluation of theophylline gastroretentive mucoadhesive tablets prepared by using natural gum. Journal of pharmacy research. 2010; 3 (8): 1961-66.
- [12]. Soltani S, Kadri M, Kaipanchery V, Stachowicz-Kuśnierz A, Korchowicz B, Rogalski M, Magri P, Korchowicz J. Experimental and computational studies of gliclazide inclusion complexes with  $\beta$ -cyclodextrin. Journal of Molecular Structure. 2024 Jan 5;1295:136645.
- [13]. Boddupalli, B., Mohammed, Z., Nath, R., & Banji, D. (2010). Mucoadhesive drug delivery system: An overview. Journal of Advanced Pharmaceutical Technology Amp Research, 1(4), 381. <https://doi.org/10.4103/0110-5558.76436>
- [14]. Raza SA, Akram J, Aamir AH, Ahmedani Y, Hassan MI. Evaluation of the effectiveness and tolerability of gliclazide modified release 60 mg in patients with type 2 diabetes observing fasting during Ramadan in Pakistan: An analysis from the global DIA-RAMADAN study. Diabetes Research and Clinical Practice. 2021 Nov 1;181:109086.

- [15]. Mohammadi, S. Z., Tajik, S., Tashakkorian, H., Zhang, K., Van Le, Q., Saecidi, S., Jang, H. W., Shokouhimehr, M., & Peng, W. (2020). Voltammetric determination of antidiabetic drug gliclazide in the presence of glibenclamide in real samples. *International Journal of Electrochemical Science*, 15(9), 8595–8611. <https://doi.org/10.20964/2020.09.49>
- [16]. Patel, S., Scott, N., Patel, K., Mohlyuk, V., McAuley, W. J., & Liu, F. (2020). Easy to swallow “Instant” jelly formulations for sustained release gliclazide delivery. *Journal of Pharmaceutical Sciences*, 109(8), 2474–2484. <https://doi.org/10.1016/j.xphs.2020.04.018>
- [17]. Hassanein, M., Sifri, S. A., Shaikh, S., Raza, S. A., Akram, J., Pranoto, A., Rudijanto, A., Shaltout, I., Fariduddin, M., Mohamed, W. M. I. W., Awadi, F. A., & Alessa, T. (2020). A real-world study in patients with type 2 diabetes mellitus treated with gliclazide modified-release during fasting: DIA-RAMADAN. *Diabetes Research and Clinical Practice*, 163, 108154. <https://doi.org/10.1016/j.diabres.2020.108154>
- [18]. Paul, S., Asha, K. F., Alam, I. Z., Ali, M. A., Al-Mamun, M. E., & Rahman, M. B. M. (2023). Physicochemical reports of gliclazide-carplex solid dispersions and tablets prepared with directly compressible co-processed excipients. *Heliyon*, 9(12), e22899. <https://doi.org/10.1016/j.heliyon.2023.e22899>
- [19]. Soltani S, Kadri M, Kaipanchery V, Stachowicz-Kuśnierz A, Korchowiec B, Rogalski M, Magri P, Korchowiec J. Experimental and computational studies of gliclazide inclusion complexes with  $\beta$ -cyclodextrin. *Journal of Molecular Structure*. 2024 Jan 5;1295:136645.
- [20]. Boddupalli, B., Mohammed, Z., Nath, R., & Banji, D. (2010). Mucoadhesive drug delivery system: An overview. *Journal of Advanced Pharmaceutical Technology Amp Research*, 1(4), 381. <https://doi.org/10.4103/0110-5558.76436>
- [21]. Szekalska, M., Puciłowska, A., Szymańska, E., Ciosek, P., & Winnicka, K. (2016). Alginate: Current use and future perspectives in pharmaceutical and biomedical applications. *International Journal of Polymer Science*, 2016, 1–17. <https://doi.org/10.1155/2016/7697031>
- [22]. Ahmad, S., Singh, V., & Kushwaha, S. K. (2025). Formulation and evaluation of gastro retentive floating microspheres of gliclazide. *International Journal of Pharmaceutical Sciences Review and Research*, 85(3). <https://doi.org/10.47583/ijpsrr.2025.v85i3.011>
- [23]. Martin, L. (2003b). Sustained buccal delivery of the hydrophobic drug denbufylline using physically cross-linked palmitoyl glycol chitosan hydrogels. *European Journal of Pharmaceutics and Biopharmaceutics*, 55(1), 35–45. [https://doi.org/10.1016/s0939-6411\(02\)00118-2](https://doi.org/10.1016/s0939-6411(02)00118-2)
- [24]. Jagdale, S. C., Agavekar, A. J., Pandya, S. V., Kuchekar, B. S., & Chabukswar, A. R. (2009b). Formulation and evaluation of gastroretentive drug delivery system of propranolol hydrochloride. *AAPS PharmSciTech*, 10(3), 1071–1079. <https://doi.org/10.1208/s12249-009-9300-8>
- [25]. Aleti, R., Baratam, S. R., Jagirapu, B., & Kudamala, S. (2021). FORMULATION AND EVALUATION OF METFORMIN HYDROCHLORIDE AND GLICLAZIDE SUSTAINED RELEASE BILAYER TABLETS: a COMBINATION THERAPY IN MANAGEMENT OF DIABETES. *International Journal of Applied Pharmaceutics*, 343–350. <https://doi.org/10.22159/ijap.2021v13i5.41339>
- [26]. El-Ashmawy AA, Abdou AR, Taha NF, Elsayed EW, Mahmoud KM, Emara LH. Formulation, pharmacokinetics evaluation, and IVIVC assessment of gliclazide multiparticulates in rat model. *Aaps Pharmscitech*. 2021 Apr 30;22(4):146.
- [27]. Mudunuru, N. L., Janjanam, K. C., & Saripilli, R. (2024b). Design and characterization of fast dissolving solid dispersion tablets of gliclazide. *International Journal of Pharmaceutical Investigation*, 14(3), 873–880. <https://doi.org/10.5530/ijpi.14.3.97>
- [28]. Trailokya, A. A., Wankhede, S., Shirsat, A., & Talware, A. (2025). Place of new generation sulfonylurea: Gliclazide in the evolving landscape of Type 2 diabetes management. *Diseases & Research*, 5(2), 111–116. <https://doi.org/10.54457/dr.202501003>
- [29]. Shahidulla, S., Khan, Z., & Imtiyaz, M. (2025). Advances in Buccal Films: A Promising Platform for Oral Mucosal Drug Delivery: An updated review. *Journal of Drug*



- Delivery and Therapeutics, 15(10), 98–103.  
<https://doi.org/10.22270/jddt.v15i10.7388>
- [30]. Adelnia, H., Ensandoost, R., Moonshi, S. S., Gavgani, J. N., Vasafi, E. I., & Ta, H. T. (2021b). Freeze/thawed polyvinyl alcohol hydrogels: Present, past and future. *European Polymer Journal*, 164, 110974. <https://doi.org/10.1016/j.eurpolymj.2021.110974>
- [31]. Begum Z, Nawab A, Ahmed MN, Shahab S, Aleem S, Akhter A, Ali A, Sattar SA. Polymeric Frontiers in Gastroretentive Drug Delivery: From Benchside Innovation to Clinical Reality. *Pak-Euro Journal of Medical and Life Sciences*. 2025 Dec 31;8(4):859-74.