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## POLYMER BASED GASTRO RETENTIVE DRUG DELIVERY SYSTEMS FOR SUSTAINED AND SITE SPECIFIC ACTION

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### ABSTRACT

Gastro-retentive drug delivery systems (GRDDS) have emerged as an important new area of research in the field of oral pharmaceuticals, where the goal is to increase the therapeutic effect of a drug by extending the time it spends in the stomach, thereby improving its bioavailability. Current trends in GRDDSs involve the continual updating and expanding of the various types of GRDDS architecture, which include some higher-level floating GRDDS, mucoadhesive and bioadhesive formulations, expandable and swelling matrices, and superporous hydrogels. This is being done to provide for optimal retention and controlled release of these forms of drugs within the stomach. New polymer technologies, particularly biodegradable and other natural polymers, continue to be researched to improve the biocompatibility, while at the same time addressing the issues associated with safety and regulations surrounding their use. Also, the use of nanotechnology is becoming increasingly common within GRDDS systems, as both nanoparticle-based carriers and microspheres provide superior targeting accuracy, stability, and mucosal interaction. These developments are making GRDDS a more effective, patient-centric oral drug delivery system with significant clinical benefits.

**Keywords:** *Gastro Drug Delivery, bioavailability, nano-carriers, dosage forms, adhesive formulations.*

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### INTRODUCTION

Oral administration is the most common and preferred route for drug delivery because of its convenience, cost-effectiveness, and high level of patient compliance. It eliminates the need for invasive procedures, is simple to manufacture, and ensures better acceptance compared to parenteral routes. Despite these advantages, conventional oral dosage forms often suffer from major physiological limitations. The most significant drawback is the unpredictable gastric emptying time, which results in premature transit of the drug into the intestine, leading to incomplete drug release and reduced systemic bioavailability. This issue becomes more critical for drugs that have a narrow absorption window in the upper gastrointestinal tract, exhibit poor solubility at alkaline pH, are unstable in

intestinal fluids, or are intended for local action in the stomach [1]. To overcome these challenges, gastroretentive drug delivery systems (GRDDS) have been developed to prolong the gastric residence time of dosage forms. Various formulation-related factors such as polymer type (nonionic, cationic, and anionic polymers), polymer composition, viscosity grade, molecular weight, and drug solubility significantly affect the quality and performance of gastroretentive dosage forms. Proper selection and optimization of these parameters are essential to ensure prolonged retention, controlled drug release, and formulation stability [2]. Gastroretentive drug delivery systems address this dual challenge by synchronizing drug release kinetics with prolonged gastric retention, thereby improving therapeutic efficacy, reducing dosing frequency, and enhancing patient compliance [3].

## 1. ANATOMY AND PHYSIOLOGY OF STOMACH

The stomach is a muscular, hollow organ in the upper gastrointestinal tract of humans and many other animals, including several invertebrates. The Ancient Greek name for the stomach is gaster which is used as gastric in medical terms related to the stomach. The stomach has a dilated structure and functions as a vital organ in the digestive system. The stomach is involved in the gastric phase of digestion, following the cephalic phase in which the sight and smell of food and the act of chewing are stimuli. In the stomach a chemical breakdown of food takes place by means of secreted digestive enzymes and gastric acid. It also plays a role in regulating gut micro biota, influencing digestion and overall health [4].

The stomach is located between the oesophagus and the small intestine. The pyloric sphincter controls the passage of partially digested food (chyme) from the stomach into the duodenum, the first and shortest part of the small intestine, where peristalsis takes over to move this through the rest of the intestines.

## 2. RATIONALE AND NEEDS FOR GRDDS

Conventional oral drug delivery systems often fail to provide optimal therapeutic outcomes due to unpredictable gastric emptying, short gastric residence time, and rapid intestinal transit. These limitations are particularly problematic for drugs that are absorbed primarily in the stomach or upper part of the small intestine, exhibit poor solubility at alkaline pH, or are intended for local action in the gastric region. The fundamental rationale behind the development of GRDDS is to synchronize the rate of drug release with gastric retention time, allowing efficient absorption and improved bioavailability. These systems are specifically designed to overcome physiological constraints associated with conventional oral dosage forms.

The rationale for GRDDS includes

- Enhancement of bioavailability for drugs with a narrow absorption window.
- Reduction in dosing frequency, especially for drugs with short biological half-lives.
- Minimization of peak–trough plasma level fluctuations, improving safety and efficacy
- Prolonged local therapeutic action in the stomach (e.g., peptic ulcer disease).
- Improved patient compliance due to simplified dosing regimens.

## 3. CLASSIFICATION OF GRDDS

Gastro retentive drug delivery systems are designed to retain drug or dosage form in the stomach for a maximum time and release their active ingredients and thereby enhances sustained and prolonged uptake of the drug in the upper part of the gastrointestinal (GI) tract. Gastro retentive delivery system can be classified as follows.

### 3.1 Bio adhesive Drug Delivery System

Bioadhesive systems adhere to the gastric mucosa using polymers like Carbopol and chitosan, prolonging gastric residence time. The drug is released slowly while the dosage form remains attached to the stomach wall. This improves bioavailability for drugs absorbed in the upper GIT, though mucus turnover may reduce adhesion time [5].

### 3.2 Expandable Drug Delivery System

Expandable systems increase in size after reaching the stomach by swelling or unfolding [6]. The enlarged dosage form prevents passage through the pylorus, ensuring prolonged gastric retention and sustained drug release. Proper design is required to avoid obstruction.

### 3.3 Floating Drug Delivery System

Floating systems have lower density than gastric fluid, allowing them to remain buoyant. Gas-generating agents produce CO<sub>2</sub>, which reduces tablet density and keeps it floating. This enhances absorption of drugs with a narrow absorption window. Floating drug delivery system can be divided into (i) Non-effervescent and (ii) Gas-generating system [7].

### 3.4 High density systems

High density systems contain heavy materials like barium sulfate to achieve density above gastric fluid. They sink and remain at the bottom of the stomach for controlled drug release. However, achieving the required density is technically challenging.

## 4. POLYMERS USED IN GRDDS

Polymers in Gastroretentive Drug Delivery Systems (GRDDS) are natural, semi-synthetic, or synthetic macromolecules incorporated into formulations to regulate drug release and modify system properties by imparting buoyancy, swelling, bioadhesion, or density control, these polymers extend gastric residence, optimize therapeutic retention, and significantly improve drug bioavailability. Some of them are mentioned below.

### 4.1 NATURAL

#### A) Sodium Alginate

Source: Extracted from the cell walls of brown seaweeds (Phaeophyceae) such as Laminaria, Macrocystis, and Ascophyllum. Structure: Linear anionic polysaccharide composed of two uronic acid monomers:

- β-D-mannuronic acid (M)
- α-L-guluronic acid (G)

Properties:

- Water soluble
- Gel-forming in the presence of divalent cations (especially Ca<sup>2+</sup>)
- pH sensitive
- Biodegradable, biocompatible, FDA-GRAS polymer

Polymeric Roles and Mechanistic Impact in

**Gastroretentive Systems:**

- Floating systems: Forms a gel barrier on contact with gastric acid, entrapping CO<sub>2</sub> bubbles and reducing density
- Controlled release: Gel matrix slows drug diffusion, providing sustained release
- Mucoadhesion: Carboxyl groups interact with gastric mucin via hydrogen bonding
- Targeted delivery: Particularly useful for gastric-localized drug delivery and H. pylori eradication

**B) Chitosan**

Source: Obtained by deacetylation of chitin, derived from shells of crustaceans such as shrimp and crab. Structure: Linear cationic polysaccharide composed of  $\beta$ -(1 $\rightarrow$ 4)-linked D-glucosamine units.

**Properties:**

- Positively charged in acidic pH
- Biodegradable and biocompatible
- High mucoadhesive strength
- Swellable in gastric fluid [8].

**Polymeric Roles and Mechanistic Impact in Gastroretentive Systems**

- Mucoadhesion: Electrostatic interaction between protonated amino groups and negatively charged gastric mucin
- Controlled release: Forms swollen matrices that regulate drug diffusion [9].
- Floating systems: Swelling reduces system density, aiding buoyancy [10].
- Targeted delivery: Enhances gastric residence and localized drug action

**4.2 SEMI-SYNTHETIC****A) Hydroxypropyl Methylcellulose (HPMC)**

Source: Hydroxypropyl methylcellulose is a semi-synthetic polymer derived from natural cellulose obtained from plant fibers such as cotton or wood pulp through chemical modification. Structure: It consists of a cellulose backbone substituted with hydroxypropyl and methoxy functional groups, which impart hydrophilic and swellable characteristics.

**Properties**

- Non-ionic and water soluble
- Available in various viscosity grades
- Forms a strong gel barrier upon hydration
- Chemically stable, biocompatible, and non-toxic [11].

**Polymeric Roles and Mechanistic Impact in Gastroretentive Systems**

- Controlled release: Upon contact with gastric fluid, HPMC hydrates and forms a viscous gel layer that regulates drug diffusion and matrix erosion
- Floating systems: Swelling and air entrapment within the hydrated matrix reduce density, enabling prolonged buoyancy
- Mucoadhesion: Weak hydrogen bonding with gastric mucin supports gastric retention Targeted delivery: Maintains dosage form integrity in the stomach, enabling site-specific drug release [12].

**B) Ethyl Cellulose**

Source: Ethyl cellulose is a semi-synthetic polymer obtained by ethylation of cellulose derived from natural plant fibers. Structure: Cellulose backbone substituted with ethyl groups, making the polymer hydrophobic in nature.

**Properties**

- Water insoluble
- pH independent
- Excellent film-forming property
- High mechanical strength [13].

**Polymeric Roles and Mechanistic Impact in Gastroretentive Systems**

- Controlled release: Acts as a release-retarding polymer by forming insoluble matrices or coatings
- Floating systems: Used in combination with hydrophilic polymers to maintain buoyancy
- Mucoadhesion: Limited mucoadhesive property; mainly acts as structural support
- Targeted delivery: Ensures prolonged release of drug in gastric environment [14].

**4.3 SYNTHETIC POLYMERS****A) Carbopol (Carbomer)**

Source: Carbopol is a fully synthetic high-molecular-weight polymer produced by polymerization of acrylic acid and cross-linked with polyalkenyl ethers. Structure: It consists of a cross-linked polyacrylic acid network containing a large number of carboxylic acid functional groups.

**Properties**

- Highly swellable in aqueous media
- Strong mucoadhesive nature
- pH-dependent viscosity
- Biocompatible and non-toxic

**Polymeric Roles and Mechanistic Impact in Gastroretentive Systems**

- Mucoadhesion: Carboxyl groups form strong hydrogen bonds with gastric mucin, enhancing adhesion to the stomach wall
- Controlled release: Swollen gel matrix retards water penetration and drug diffusion
- Floating systems: Swelling contributes to volume expansion and buoyancy when combined with gas-forming agents
- Targeted delivery: Maintains drug at the gastric site for prolonged local and systemic action

**B) Polyvinyl Alcohol (PVA)**

Source: Polyvinyl alcohol is a synthetic polymer obtained by hydrolysis of polyvinyl acetate.

Structure: Linear polymer with repeating vinyl alcohol units containing hydroxyl groups.

**Properties**

- Water soluble
- Good film-forming property
- High tensile strength
- Biocompatible [15].

## Polymeric Roles and Mechanistic Impact in Gastroretentive Systems

- Controlled release: Forms uniform matrices that regulate drug release
- Floating systems: Swelling and air entrapment assist buoyancy
- Mucoadhesion: Hydrogen bonding with gastric mucosa
- Targeted delivery: Improves residence time in stomach [16].

## 5. EVALUATION PARAMETERS OF GRDDS

### 5.1. Physical Characterization

- Appearance and Shape: Visual inspection for uniformity, surface defects, cracks, or deformation.
  - Tablet Dimensions (Thickness and Diameter): Measured using vernier calipers to ensure batch uniformity.
- Hardness (Crushing Strength): Determines mechanical strength to withstand gastric motility while maintaining buoyancy.
- Friability: Evaluated using a friabilator to assess resistance to abrasion during handling.
- Weight Variation: Ensures dose uniformity as per pharmacopeial limits.

### 5.2 Total Floating Time (TFT)

- Represents the duration for which the dosage form remains buoyant on gastric fluid
- Indicates the effectiveness of floating mechanism
- Ideal GRDDS should float for more than 12-24 hours

### 5.3 In Vitro Buoyancy Studies

- Conducted in simulated gastric fluid at  $37 \pm 0.5$  °C
- Observes floating behavior, position, and stability
- Confirms low-density and gas entrapment efficiency

### 5.4. Swelling Index

- Measures the extent of water uptake and polymer swelling and is Calculated using the formula:

$$\text{Swelling Index} = \frac{W_t - W_o}{W_o}$$

where  $W_t$  weight at time  $t$  and  $W_o$  = initial weight

- Swelling plays a key role in buoyancy, mucoadhesion, and controlled release

### 5.5 Mucoadhesive Strength (if applicable)

- Evaluates the adhesive force between dosage form and gastric mucosa
- Determined using texture analyzer or modified balance method
- Higher mucoadhesive strength enhances gastric retention

### 5.6 In Vitro Drug Release Studies

- Performed using USP dissolution apparatus (Type I or II)
  - Medium: Simulated gastric fluid (pH 1.2)
- Determines release kinetics and mechanism (diffusion, erosion, swelling)

### 5.7 Drug Release Kinetics

- Release data fitted to mathematical models:
- Zero-order

- First-order
- Higuchi model
- Korsmeyer–Peppas model
- Helps understand mechanism of drug release

## 6. RECENT ADVANCE 3D PRINTING TECHNOLOGY IN GRDDS

The use of 3D (three-dimensional or three dimensional) printing has become one of the major developments in the evolution of Gastroretentive Drug Delivery Systems (GRDDS). In contrast to traditional manufacturing methods, 3D printing enables a high throughput of control of the geometry of the tablet, the internal structure, density, and drug distribution. This facilitates the production of tailor made dosage forms which are specifically aimed at fostering gastrointestinal retention. Floating, expandable, and multi-layered gastroretentive systems are typically prepared by methods that include Fused Deposition Modeling (FDM), Stereolithography (SLA) and Semi-Solid Extrusion (SSE). In floating GRDDS, the 3D printing method is applied to produce hollow or porous materials with low density, which ensures that the dosage form can be retained in the gastric fluid over a long period of time. In the case of expandable systems, complicated foldable or swellable designs can be printed, which swell when in contact with the gastric fluid and do not allow the passage of a pylorus. Multi-compartment tablets with different drugs or drug release rates, which allow combination therapy and controlled drug release of a single device, are also supported by the technology.

The other key breakthrough is the creation of customized GRDDS. 3D printing provides an opportunity to customize doses according to the specifics of the patient age, weight, and disease. Further, biodegradable and stimuli-responsive polymers, which enhance safety and controlled degradation after drug release, are used. All in all, 3D printing is flexible regarding formulation, has a higher capacity to control drug release with high precision, and a future-oriented solution to gastroretentive drug delivery systems.

## 7. APPLICATIONS OF POLYMERS IN GRDDS

- Floating System Formulation-Polymers form a gel matrix that reduces density and maintains buoyancy in gastric fluid.
- Mucoadhesive Drug Delivery-Bioadhesive polymers enable attachment to gastric mucosa, prolonging residence time.
- Swelling and Expandable Systems-Swellable polymers increase dosage form size to prevent premature gastric emptying.
- Controlled / Sustained Drug Release-Polymers regulate drug diffusion and erosion to maintain prolonged release.
- Matrix Formation and Structural Integrity-Polymers provide mechanical strength and stability to the dosage form.

- Gas Generation and Entrapment-Polymers help entrap generated CO<sub>2</sub> to support floating mechanisms.
- Protection from Gastric Environment-Polymers protects drugs from acidic degradation in the stomach.
- Site-Specific Drug Delivery-Polymers enable targeted drug release in the upper gastrointestinal tract.

## 8. FUTURE PERSPECTIVES OF GRDDS

The future visions of gastroretentive drug delivery systems (GRDDS) point out that despite the numerous attempts to study different gastroretentive technologies, most of them have their own limitations, especially the large range of gastrointestinal residence times (GRT) in the fed and fasted states. This physiological heterogeneity is still one of the greatest problems in obtaining the same gastroretention and no single GRDDS strategy seems to fully resolve them. In turn, the trend of future studies is the creation of combination or dual-mechanism systems, i. e. of expandable floating systems, mucoadhesive floating systems, swellable floating systems and mucoadhesive high-density systems that have the potential to reduce the variability of GRT and guarantee delayed gastric emptying. These dual working systems are less affected by the physiological conditions of the gut and especially the fasted and fed states and therefore more reliable at the gastric retention despite adverse working conditions. Moreover, the further development of GRDDS must take a case-by-case approach to evaluation because the parameters of the physicochemical characteristics of the drug and excipients, the type, and composition of the polymer, drug dose, and the ability to manufacture it are quite product-specific. Moreover, sophisticated in vivo testing methods such as radiology and scintigraphy are likely to be important in the correct determination of dosage form gastric emptying and gastric retention behaviour, and magnetic marker monitoring methods may be considered more frequently to depict real time images of gastroretentive system in the stomach [17]. Taken together, these approaches indicate that the future of GRDDS is in mechanism-combination designs, QbD-driven development, and strong in vivo testing to realize predictable and long-term gastric retention [18].

## 9. CONCLUSION

Gastromimetic drug delivery systems are an appropriate solution to increase the bioavailability and therapeutic effectiveness of the drugs with a small absorption window, local gastric effect or unstable in the intestinal environment. Despite the development of a great variety of GRDDS technologies including floating, mucoadhesive, expandable and high-density systems, the variable gastric residence time, especially under fed and fasted conditions is a significant issue. The further development of the field is based on

rational development of combination or dual-mechanism gastroretentive systems, enhanced with the help of the innovative polymeric materials, Quality by Design strategy of formulations development, and stable in vivo testing methods. As the field of formulation science, manufacturing technologies and regulatory knowledge continue to evolve, GRDDS will likely become trustworthy and clinically useful oral drug delivery systems with the capacity to assure a consistent degree of gastric retention, controlled drug release and enhanced patient compliance.

## 10. AUTHOR CONTRIBUTIONS

All authors are contributed equally.

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None

## 12. DECLARATION COMPETING INTEREST

The authors have no conflicts of interest to declare.

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## 14. REFERENCES

1. Streubel A, Siepmann J, Bodmeier R. Gastroretentive drug delivery systems. *Expert Opin Drug Deliv.* 2006;3(2):217-233.
2. Swetha S, Allena RT, Gowda DV. A comprehensive review on gastroretentive drug delivery systems. *Int J Pharm Biomed Res.* 2012;3:1285-1293.
3. Pund AU, Shendge RS, Pote AK. Current approaches on gastroretentive drug delivery systems. *J Drug Deliv Ther.* 2020;10(1):139-146.
4. Sarparanta MP, Bimbo LM, Mäkilä EM, Salonen JJ, Laaksonen PH, Helariutta AK, Linder MB, Hirvonen JT, Laaksonen TJ, Santos HA, Airaksinen AJ. The mucoadhesive and gastroretentive properties of hydrophobin-coated porous silicon nanoparticle oral drug delivery systems. *Biomaterials.* 2012;33(11):3353-3362.
5. Chavanpatil MD, Jain P, Chaudhari S, Shear R, Vavia PR. Novel sustained release, swellable and bioadhesive gastroretentive drug delivery system for ofloxacin. *Int J Pharm.* 2006;316(1-2):86-92.
6. Klausner EA, Lavy E, Friedman M, Hoffman A. Expandable gastroretentive dosage forms. *J Control Release.* 2003;90(2):143-162.
7. Arora S, Ali J, Ahuja A, Khar RK, Baboota S. Floating drug delivery systems: A review. *AAPS PharmSciTech.* 2005;6(3):E372-E390.
8. Ishak RA. Buoyancy-generating agents for stomach-specific drug delivery: An overview with special emphasis on floating behavior. *J Pharm Pharm Sci.* 2015;18(1):77-100.
9. Anal AK, Stevens WF. Chitosan-alginate multilayer beads for controlled release of ampicillin. *Int J Pharm.* 2005;290(1-2):45-54.

10. Singla AK, Chawla M. Chitosan: Some pharmaceutical and biological aspects-an update. *J Pharm Pharmacol*. 2001;53(8):1047-1067.
11. Li S, Lin S, Daggy BP, Mirchandani HL, Chien YW. Effect of HPMC and Carbopol on the release and floating properties of gastric floating drug delivery system using factorial design. *Int J Pharm*. 2003;253(1-2):13-22.
12. Phadtare D, Phadtare G, Nilesh B, Asawat M. Hypromellose—A choice of polymer in extended release tablet formulation. *World J Pharm Pharm Sci*. 2014;3(9):551-566.
13. Hegyesi D. Study of the widely used ethylcellulose polymer as film forming and matrix former agent [doctoral dissertation]. Szeged (Hungary): University of Szeged; Year not specified.
14. Soppimath KS, Kulkarni AR, Rudzinski WE, Aminabhavi TM. Microspheres as floating drug-delivery systems to increase gastric retention of drugs. *Drug Metab Rev*. 2001;33(2):149-160.
15. Yang SH, Ju XJ, Deng CF, Cai QW, Su YY, Xie R, Wang W, Liu Z, Pan DW, Chu LY. Controllable fabrication of monodisperse poly(vinyl alcohol) microspheres with droplet microfluidics for embolization. *Ind Eng Chem Res*. 2022;61(34):12619-12631.
16. Prinderre P, Sauzet C, Fuxen C. Advances in gastroretentive drug-delivery systems. *Expert Opin Drug Deliv*. 2011;8(9):1189-1203.
17. Prajapati VD, Jani GK, Khutliwala TA, Zala BS. Raft forming system—An upcoming approach of gastroretentive drug delivery system. *J Control Release*. 2013;168(2):151-165.
18. Tripathi J, Thapa P, Maharjan R, Jeong SH. Current state and future perspectives on gastroretentive drug delivery systems. *Pharmaceutics*. 2019;11(4):193.