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Review Article

A Review On Gastro Retentive Drug Delivery System: Novel Approach With The Future Perspectives

Satbir Singh[1], Kehar Singh*[2], Yogita[3], Hemant Rana[4]

[1,2]*Associate Professor, Pt. LR Group of Institutions, Faridabad*
[3]*Undergraduate, Pt. LR College of Pharmacy, Faridabad*
[4]*Undergraduate, Pt. LR College of Pharmacy, Faridabad*

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ABSTRACT

Drugs with an absorption window can benefit from more regulated administration when they are administered with GRDDSs because they release the drug continuously for a longer amount of time before it reaches the absorption site. Just because of gastro-retentive drug delivery devices, medications are meant to remain in the stomach for an extended amount of time (GRDDS). This could be beneficial for drugs that must be taken gradually or that are hydrolyzed by stomach acid. GRDDS are a new and exciting technology that could improve medication delivery to the gastrointestinal tract. Their potential is to reduce the negative effects of drugs while simultaneously improving their safety and efficacy. The primary goal of GRDDS is to improve the therapeutic efficacy and bioavailability of drugs taken orally. There are several forms of GRDDS available, including tablets, capsules, and multi-particulate systems. They are manufactured using a range of methods, including as expandable, muco-adhesive, and floating systems, to accomplish gastro-retention. The primary goals of this review paper are to go over the fundamental idea behind GRDDS, the most recent technique for GRDDS, and the state of GRDD delivery at the moment. In this review, we talk about the physiological condition of the stomach and the several elements that affect GRDDS. This review article also provides a brief overview of the benefits and drawbacks of newly developed gastrointestinal technologies, such as sticky, muco-adhesive, low- and high-density systems, and expandable.

INTRODUCTION

Because of oral drug delivery systems' numerous advantages—such as high patient compliance, affordability, convenience of storage and transportation, formulation flexibility, and ease of administration—they have replaced other drug delivery methods for human administration. Oral drug administration techniques encounter a

***Corresponding Author:** Kehar Singh
Address: *Associate Professor, Pt. LR Group of Institutions, Faridabad*
Email : keharpharma88@gmail.com

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number of challenges, including low bioavailability due to the heterogeneity of the gastrointestinal tract, bacterial pH, the dosage form's stomach retention time, surface area, and enzymatic activity. A type of drug delivery system called GRDDS is designed to increase a medication's half-life in the stomach. [1]. This may be advantageous for medications that must be administered to the stomach, are sensitive to stomach acid, or are poorly absorbed in the small intestine. Upper GIT drug release is the focus of GRDDS, a technique for extending GRT that has both local and systemic effects. GRDDS can enhance regulated administration of medication with an absorption window by releasing the medication for a longer period of time prior to it reaching the absorption site. Prolonging a drug's residence duration in the stomach is the aim of a gastro-retentive drug delivery system (GRDDS) [1-2]. There are several ways to accomplish this, including: Floating systems, Muco-adhesive systems, Magnetic systems, Expandable systems. [1-3]. GRDDS are used for a variety of drugs, including as shown in table 1.

Table: 1 Drugs used for GRDDS with examples

Sr. No	Drug Candidate	Example
1	Drugs that are absorbed from the stomach	Proton Pump inhibitor like omeprazole, lansoprazole
2	Drugs that are labile at alkaline pH	ranitidine, metformin
3	Drugs that are poorly soluble at alkaline pH	furosemide, diazepam
4	Drugs that have a narrow window of absorption	riboflavin, levodopa

GRDDS are a good choice for drugs that have short half-lives, poor solubility at alkaline pH, low absorption in the bottom half of the GIT, and local activity in the upper part of the gut for the eradication of Helicobacter pylori. GRDDS is a potentially helpful technique for improving medicine delivery to the stomach. They provide a number of advantages over conventional oral pharmaceutical administration techniques, and research is being done on possible applications. [3]

Advantages and Disadvantages of GRDDS

It is important to consider the several advantages and disadvantages of GRDDS when developing or applying this drug delivery technique. The main benefits and drawbacks of GRDDS for compositional progress are as follows:

Advantages

GRDDS have a number of advantages, but they also have some disadvantages. The merits of GRDDS as below followings:

i. By keeping poorly water-soluble medications in the stomach, where absorption can take place, GRDDS can improve the drug's absorption.
ii. ii. They make sustained medication release possible, which may lead to less frequent dosage and a lengthier therapeutic impact.
iii. Additionally, controlled release helps lessen variations in the circulation levels of the medicine, which may minimize adverse effects. [2-4].

Disadvantages

Although they have many benefits, gastro-retentive medication delivery devices also have certain drawbacks. The following are GRDDS' drawbacks:

i. GRDDS can be difficult to target specific stomach areas, especially if the medicine is administered gradually. This could be problematic for drugs that need to be released in a specific area of the stomach for optimal absorption or therapeutic effect.

ii. Additionally, esophageal binding with bio-adhesive drug delivery methods is a potential.
iii. Not all medications are compatible with GRDDS. GRDDS, for example, may not hold onto drugs that easily dissolve in stomach acid.
iv. GRDDS can raise the possibility of a medication's negative effects, particularly if it is released too quickly or too slowly.
v. GRDDS development and manufacturing may be more expensive than that of other drug delivery methods.
vi. Their stomachs must hold a lot of fluid in order for them to float and function properly. Consequently, when using this dose form, it is recommended to consume more water. [2-5].

Drug selection criteria for GRDDS

i. A number of considerations should be made while selecting drugs for Gastro-retentive Drug Delivery Systems (GRDDS) to ensure that the medication is suitable for this kind of delivery system. The main factors used to choose GRDDS medications are:
ii. GRDDS are especially useful for drugs that are poorly soluble and have low permeability in the gastrointestinal tract. These drugs often have limited absorption in the upper GI tract; therefore, prolonging their residence duration can increase their bioavailability.
iii. For drugs with a restricted window of absorption in the stomach or upper small intestine, GRDDS is advantageous. These systems can increase the chance of absorption by making sure the drug remains in the absorption site for a longer period of time. [3–7].
iv. The stability or solubility of some drugs changes with pH. GRDDS can be designed to release the medication in response to the pH of the stomach, ensuring optimal absorption.
v. Medication that undergoes significant first-pass metabolism in the liver may benefit from gastro-retentive delivery. By remaining exposed in the stomach for an extended length of time, the medicine can initially bypass the liver by decreasing metabolism and increasing systemic bioavailability.
vi. Medication with a mechanism of action unique to the stomach, like antacids or those used to treat peptic ulcers or gastro esophageal reflux disease (GERD), is a good fit for GRDDS.
vii. Certain drugs may interfere with meals or respond adversely to pH changes in the stomach. GRDDS can be designed to control the drug's release while food is present or to reduce interactions with food. [3]

Table 2: Drug selection criteria for GRDDS with drugs example [3-9]

Sr. No	Drug Selection Criteria	Example Drugs selected
1	Solubility	Poorly soluble in the small intestine but soluble in the stomach: Ranitidine, Metformin
2	Stability	Stable in the acidic environment of the stomach: Ranitidine, Sucralfate
3	Absorption	Absorbed in the stomach or upper small intestine: Ranitidine, Ondansetron
4	Pharmacokinetics	Has a long half-life so that it can be released over an extended period of time: Metformin, Ondansetron
5	Safety	Safe to be released in the stomach: Ranitidine, Sucralfate

6	Tolerability	Well-tolerated by patients: Ranitidine, Ondansetron

The GRDDS medication selection process should include a comprehensive evaluation of these criteria to determine the feasibility and potential benefits of this drug delivery approach. Additionally, collaboration with formulation experts, regulatory specialists, and pharmaceutical scientists is essential during the development stage. GRDDS is widely used to administer medications with short half-lives because it maintains a steady drug level in the bloodstream. [8]

Requirements of GRDDS

There are several reasons why a medication delivery system such as a gastro-retentive drug delivery device (GRDD) can be necessary. Some of the most common causes are as follows:

i. To improve the bioavailability of the drug
ii. To provide a sustained release of the drug
iii. To protect the drug from stomach acid
iv. To target the drug to the stomach: [6-9]

The GRDDS is a complicated mechanism for drug delivery and removal; the time and stages of the GRDDS motility pattern are displayed in the figure 1 according to the description below.

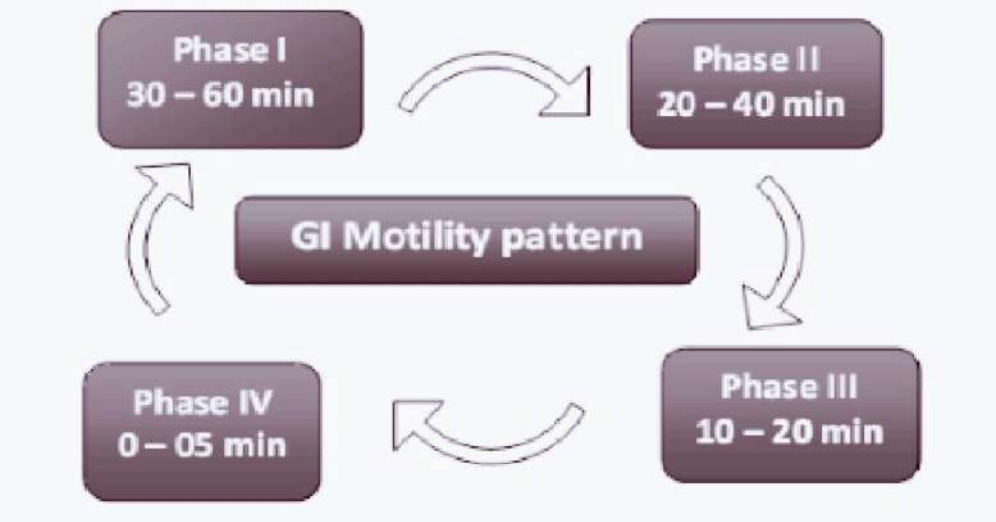

Figure 1: Motility patterns of GIT in the fasted state

Gastro-retentive drug delivery systems (GRDDS) and conventional drug delivery systems (CRDDs) differ greatly in terms of their uses, drug release procedures, and architecture. GRDDS are customized medication delivery systems designed to increase the amount of time a medication stays in the stomach or upper gastrointestinal tract. [1,9,10]. The main goal of GRDDS is to prolong the duration that the medication is in the stomach region, hence improving drug absorption. Conventional drug delivery methods are the typical pharmaceutical dose forms that are regularly used to provide medications. These include injectables, syrups, pills, capsules, and other dosage forms that typically allow the drug to enter the stomach to be absorbed and distributed there. The comparison between GRDDS and CRDDs mentioned in Table 3 as below

Table 3: Gastro-retentive Drug Delivery Systems (GRDDS) Vs Conventional Drug Delivery Systems (CRDDS) [11,12]

Sr. No	Features	GRDDS Description	CRDDS Description
1	Purpose	To prolong the residence time of a drug in the stomach.	To deliver the drug to the small intestine as quickly as possible.
2	Mechanism	Uses various mechanisms to keep the drug in the stomach, such as floating, swelling, mucoadhesion, and magnetic targeting.	Does not use any mechanisms to keep the drug in the stomach.
3	Drugs	Suitable for drugs that are poorly absorbed in the small intestine, sensitive to stomach acid, or need to be delivered to the stomach.	Suitable for a wider range of drugs.
4	Side effects	May cause nausea, vomiting, or other side effects due to the harsh environment of the stomach.	Less likely to cause side effects.
5	Efficiency	More efficient at delivering drugs to the stomach.	Less efficient at delivering drugs to the stomach.
6	Patient compliance	May be more difficult for patients to take GRDDS consistently due to the need to take them with food or on an empty stomach.	CRDDs are easier for patients to take consistently.

PHYSIOLOGY OF STOMACH

Due to its primary role in both drug release and retention, the stomach plays a crucial role in gastro-retentive drug delivery systems (GRDDS). Understanding the fundamental physiology of the stomach in GRDDS is crucial to understanding how the stomach functions and how GRDDS benefits from these physiological processes Understanding the anatomy and physiology of the stomach is essential for creating an effective gastro-retentive dosage form, as the stomach plays a significant part in GRDDS. The stomach is physically separated into two halves, as shown in Fig. 01: the proximal stomach, which contains the fundus and body, and the distal stomach, which contains the antrum and pylorus. Processing food, holding it for a short period, and then gently releasing it into the duodenum is the stomach's main function. [12] The fundus and body primarily act as storage areas for undigested food, whereas the antrum pushes food forward to assist in stomach emptying. The stomach's movement pattern is referred to as the "migrating myoelectric complex" (MMC); Table 05 shows the many stages of the MMC. While the process differs greatly between the fed and fasted stages, both involve stomach emptying. When fasting, the stomach and small intestine undergo a sequence of electrical events that cycle every 90 to 120 minutes. [17] The pylorus widens to around during the inter digestive phase. As a result, during inter digestive phase, particles smaller than the diameter of the pyloric sphincter can move readily from the pylorus to the duodenum. [21–24].

The Basic Overview of the Physiology of the Stomach in GRDDS

Gastric Emptying Time (GRT)

The stomach's primary function is to store and process food. After food is digested, the stomach begins to physically and chemically break it down. The gastric emptying duration is the amount of time it takes for the stomach to empty its contents into the small intestine (GRDDS). [16] By extending the gastric residence time, GRDDS make sure that the medication stays in the stomach for a longer amount of time before moving on to

the small intestine. The stomach's anatomy is depicted in the provided Figure

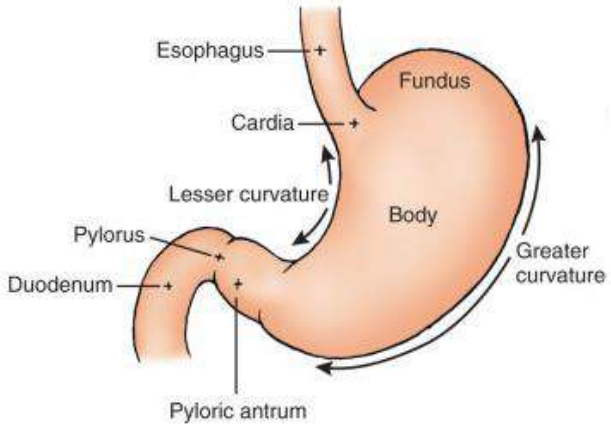

Figure 2: Anatomy of stomach Representation

Gastric Secretions

Peptides and hydrochloric acid, two gastric secretions from the stomach, help break down food into chyme, a semi-liquid mixture. GRDDS must be developed to withstand the acidic and enzymatic conditions prevalent in the stomach in order to guarantee that the medication stays stable until it is administered at the scheduled rate.

Motility and Mixing

The stomach's muscular walls flex to mix and churn food with gastric juices, facilitating full digestion. GRDDS's drug delivery technique, in instance, uses floating devices that are meant to float on top of stomach contents to provide consistent medication release and mixing. [18]. Food Reservoir: The stomach serves as a food reservoir, consistently supplying the body with nutrients even in cases of irregular meal consumption. GRDDS makes use of this reservoir function to maintain medicine delivery within the stomach.

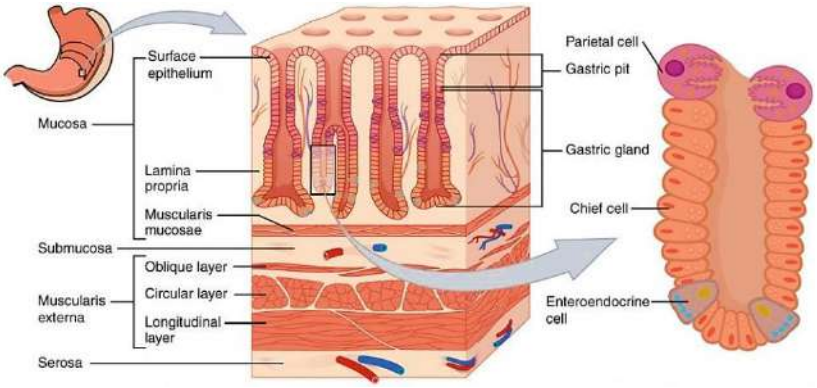

Figure 3: Schematic view physiology of GRDDS as stomach part

Pyloric Sphincter

The pyloric sphincter is the name of the muscular valve that separates the stomach from the small intestine. Since some systems are designed to adjust the sphincter's opening in order to delay or limit the release of pharmaceutical formulations into the small intestine, this sphincter can function as a control point in GRDDS. [17]

Gastric Emptying Variability

There are several factors that can cause individual variations in stomach emptying, such as the type of meal and the presence of disease. GRDDS must account for this variability since drug release

profiles must be consistent. [16] The several variables influencing the gastric retention of dose forms are described below for Table 4, which displays the relevant data.

Table 4: The various factors controlling gastric retention of dosage forms [19-27]

Sr. No	Factors Involving	Description
1	**Size and shape**	The size and shape of the dosage form can affect its gastric retention. Larger and more spherical dosage forms tend to float in the stomach, while smaller and more irregular dosage forms tend to sink.
2	**Density**	The density of the dosage form can also affect its gastric retention. Denser dosage forms tend to sink, while less dense dosage forms tend to float.
3	**Surface properties**	The surface properties of the dosage form can also affect its gastric retention. Dosage forms with hydrophilic (water-loving) surfaces tend to be more easily retained in the stomach.
4	**Stomach emptying rate**	factors, including the type of food or fluid, the presence of food in the small intestine, and the patient's medical condition.
5	**Drug properties**	The properties of the drug itself can also affect its gastric retention. Drugs that are poorly soluble in water tend to be more easily retained in the stomach, while drugs that are soluble in water tend to be more easily cleared from the stomach.

Current Pharmaceuticals Approaches of Gastrointestinal Drug Delivery System (GRDDS)

The current methods for delivering gastro-retentive medications are described in this section. The main mechanisms of GRDDS include swelling, effervescence, floating, sinking, mucoadhesion, and magnetic properties. Intestinal drug delivery systems facilitate the efficient and targeted delivery of pharmaceutical substances to the gastrointestinal tract. Many techniques and instruments have been developed to improve drug absorption, increase bioavailability, lessen side effects, and improve patient adherence. [20]. Recent approaches for GRDDS shown in Figure 4.

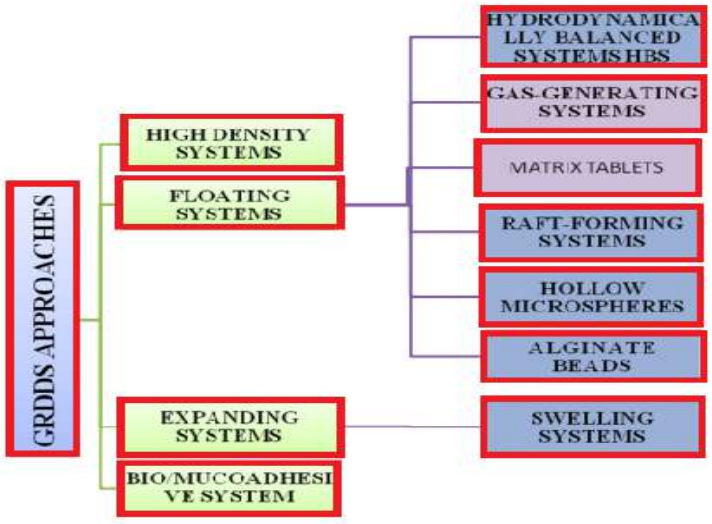

Figure 4: Flow diagram of the recent approach for GRDDS

NON-FLOATING SYSTEM

Non-floating medication delivery systems are designed to remain in the stomach for extended

periods of time without floating above its contents. Non-floating systems are a subclass of gastro-retentive drug delivery devices (GRDDS) that do not float on the surface of stomach fluid. These systems may prove advantageous for drugs that require a prolonged stomach residence period for therapeutic or absorption purposes. [21]. The four different kinds of non-floating systems are listed as follows:

1. High Density System

The purpose of high-density systems is to sink to the bottom of the stomach and remain there since their density is greater than that of gastric fluids. These systems are typically composed of denser polymers or heavier components. The stomach mucosa and the drug delivery system can have prolonged contact thanks to the high-density characteristic. [22]

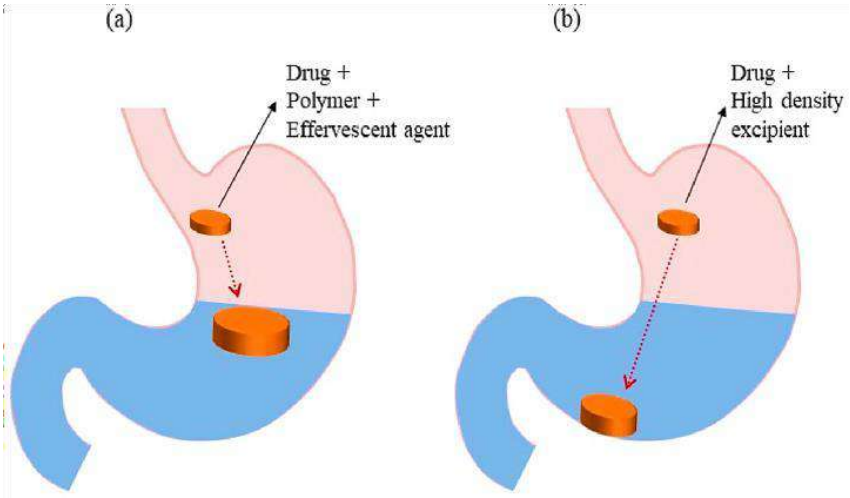

Figure 5: Schematic representation of GRDDS approach

a. Low density
b. High Density approach

2. Swelling System

The purpose of swelling systems is to expand by absorbing stomach contents. They are also known as swelling-controlled systems or extremely porous hydro gels. Because of its expansion, the pyloric sphincter prevents the system from entering the small intestine. As the system weakens and stretches over time, the drug is released (see figure 6). [20]

3. Expandable System

By expanding their volume or form, expandable drug delivery devices are intended to have a longer GRT. Its uses were first extended to the veterinary field before being extended to humans [25]. For the system to function properly, it must have three main designs: a small size for easy oral consumption, an enlarged shape in the stomach to hinder passage via the pyloric sphincter, and a smaller system size to aid in evacuation after the medication has released fully. This device is sometimes called a "plug type system" since it has the ability to block the pyloric sphincter. Expandable systems inflate in reaction to stomach contents, just like swelling systems do.

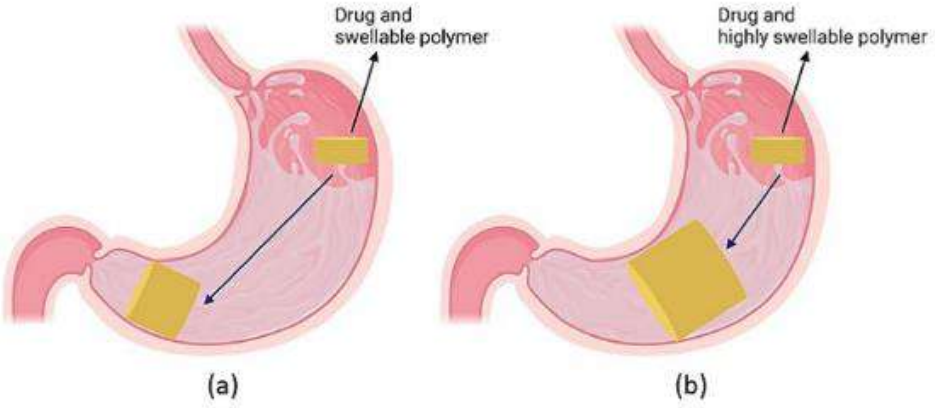

Figure 6: Schematic representation of GRDDS based non-floating approach

4. Bio-adhesive/Muco-adhesive System

In 1984, Park and Robinson provided the first description of the mucoadhesive/bioadhesive system. Its goal was to cling to the stomach epithelial cells' surface in order to extend the half-life of therapeutic substances. Using this technique, medications are mixed with a mucoadhesive agent—which could be composed of natural or synthetic polymers. The link that forms between the polymer and mucosal surface facilitates mucoadhesion. Mucoadhesive systems are designed to adhere to the stomach mucosa in order to prevent them from being swept into the small intestine. They consist of compounds or polymers that use bioadhesion to interact with the mucosal lining. Mucoadhesion enhances the drug delivery system's stomach retention to guarantee prolonged contact with the mucosa for drug release and absorption, as illustrated in figure 7. [20–29].

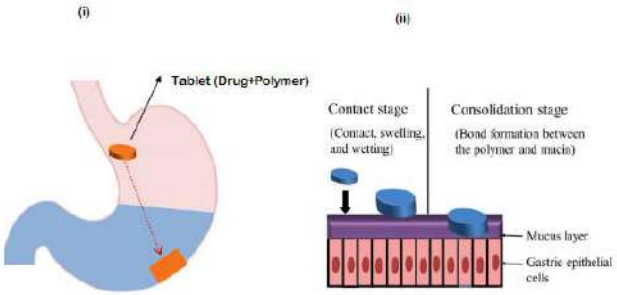

Figure 7: Mucoadhesive GRDDS (a) General representation of muco-adhesive systems and (b) Mechanism of muco-adhesive systems.

FLOATING SYSTEM

Park and Robinson first described the mucoadhesive/bioadhesive system in 1984. Its purpose was to prolong the GRT of medicinal compounds by adhering to the surface of gastric epithelial cells. This method involves the incorporation of pharmaceuticals into a mucoadhesive agent, which may be made of synthetic or natural polymers. Mucoadhesion is facilitated by the bond formed between the polymer and mucosal surface. In order to keep them from being swept into the small intestine, mucoadhesive systems are made to stick to the gastric mucosa. They include substances or polymers that interact with the mucosal lining through bio-adhesion. In order to ensure extended contact with the mucosa for drug release and

absorption, muco-adhesion improves the stomach retention of the drug delivery system. [28]

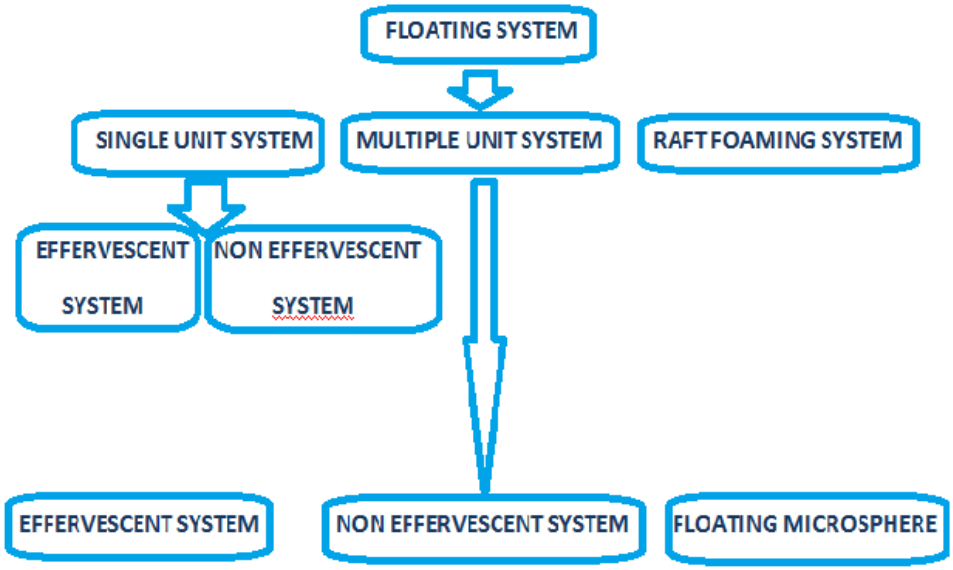

Figure 8: Flow diagram of the recent approach for the Floating system

The advantages of floating systems as following

1. They can prolong the residence time of drugs in the stomach.
2. They can protect drugs from the acidic environment of the stomach.
3. They can be used to deliver drugs to a specific location in the stomach.

The disadvantages of floating systems as following:

1. They can be difficult to formulate.
2. They can be expensive to produce.
3. They can cause side effects, such as nausea and vomiting.

One possible technological advancement for medicine delivery to the stomach is the use of floating systems. They have certain drawbacks as well as a lot of benefits over traditional oral medication delivery methods [30–31]. Floating systems are selected according on the particular medicine and the planned use. There are several types of floating systems, described as below description:

1. Single Unit Floating Dosage form System

a. Effervescent System (Gas-Generating System [32].

b. Non-Effervescent System

2. Multiple Unit Floating Dosage Form System

a. Non-Effervescent System

b. Effervescent System (Gas Generating System. [33]

c. Hollow Microspheres

3. Raft Foaming System – as shown in figure 9. [34]

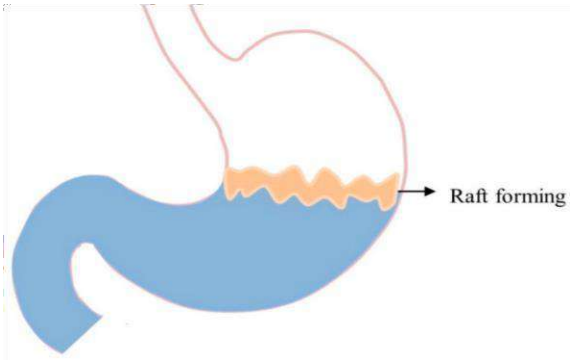

Figure 9: GRDDS based on raft-forming systems

The common differences in floating and non-floating GRDDS discussed in Table 5 as below.

Table 5: the differences between floating and non-floating GRDDS [34-38]

Sr. No	Feature	Floating GRDDS	Non-floating GRDDS
1	**Mechanism of action**	Float on the gastric fluid due to their lower density	Adheres to the stomach lining or expands in the stomach
2	**Drug delivery**	Sustained release of drug	Controlled release of drug
3	**Applications**	Drugs that are sensitive to the acidic environment of the stomach, drugs that need to be delivered in a controlled manner	Drugs that are not sensitive to the acidic environment of the stomach, drugs that need to be delivered to a specific site in the stomach
4	**Examples**	Esomeprazole delayed-release capsules (Nexium), ranitidine bismuth citrate (Tritec)	Domperidone (Motilium), lansoprazole (Prevacid), ketoprofen delayed-release capsules (Orudis KT)

Common Excipients Used With Gastro-Retentive Floating Formulations

Excipients that are used in gastro-retentive drug delivery system are listed below in table. [33]

Table 6: Common Excipients Requirements in Gastro-Retentive Floating Formulations

Sr. No.	Systems	Polymers Requirements
1	EffervescentSystems	Agar,Carbopol,HydroxypropylMethylCellulose,PolyacrylatePolymer,PolyvinylAce - tate, Sodium Alginate, Calcium Chloride, Polyethylene Oxide, Polycarbonates
2	Non-Effervescent Systems	HydroxypropylMethylCellulose,Ethylcellulose,Hydroxypropylcellulose,Carrageen, PolyvinylAcetate,Carbopol,SodiumAlginate,Agar,CalciumChloride
3.	Mucoadhesive	Carbopol,HydroxypropylMethylcellulose,Chitosan,Polycarbophil,Carbopol,Lecti ns, Carboxy Methyl Cellulose, Gliadin, Polyethylene Glycol, Tragacanth, Dextrin, Chitosan, Sodium Alginate, Cholestyramine, Poly Acrylic Acid, Sucralfate
4	Super-PorousHydrogel	CrospovidoneAndSodiumCarboxymethylcellulose
5	SwellingSystems	Acacia,Pectin,Chitosan,Agar,Casein,Bentonite,Veegum,HydroxypropylMethyl Cellulose,GellanGum,SodiumCarboxyMethylCellulose,MethylCellulose,Hydroxy Propyl Cellulose
6	ColloidalGelBarrier System	Hydroxy Propyl Cellulose, Polysaccharides, Matrix-Forming Polymer (Polycarbophil, Polyacrylate, Polystyrene)

CURRENT STATUS OF GRDDS IN MARKETED BASIS

GRDDS are currently available on the market, with several of them having been approved and

marketed for use in humans. Numerous medications, such as anti-inflammatory, anti-emetic, and anti-ulcer medications, are delivered by these GRDDS. Gastro-retentive marketed formulation with their technology shown in table 8.

Table 8: The GRDDS that are currently marketed, along with the technology they are used with drug category [33, 47, 48]

Sr. No.	Product Name	Active Pharmaceutical Ingredient	Technology	Category	Manufacturer
1	CafeclorLP	Cefaclor	MinextabFloating	Antibiotic	Galenix,France
2	InonAceTablets	Simethicone	Foam based floating system	Antacid	SatoPharma,Japan
3	CiproXR	Ciprofloxacin hydrochloride	Erodible matrix based system	Antibiotic	Bayer,USA
4	Conviron	Ferrous sulphate	Colloidal gel formingFDDS	Iron supplement	Ranbaxy,India
5	Metformin HCl LP	MetforminHCl	MinextabFloating	Antidiabetic	Galenix,France
6	CifranOD	Ciprofloxacin	Effervescent floating form	Antibiotic	Ranbaxy,India
7	GabapentinGR	Gabapentin	Polymer based swelling technology	Anticonvulsants	Depomed,USA
8	Glumetza	MetformineHCI	Polymer based swelling technology	Antidiabetic	Depomed,USA
9	Cytotec	Misoprostol	Bilayer floating capsule	Anti-Ulcer	PharmaciaLimit-ed,UK
10	Kadian	Morphine sulfate	-	Painrelief	Sumitomo Pharma, Japan
11	Madopar	Levodopaand Benserzide	Floating,CRcapsule	Anti-Parkinson's	Roche,UK
12	OflinOD	Ofloxacin	Gas-generating floating tablets	Antibiotic	
13	Metformin GR	MetformineHCl	Polymer based swelling technology	Antidiabetic	Depomed,USA
14	ProQuinXR	Ciprofloxacin	Polymer based swelling technology	Antibiotic	Depomed,USA
15	PrazopressXL	PrazosinHCl	Effervescent and swelling-based floating system	Anti-hypertension	SunPharma,Japan
16	Riomet OD	MetformineHCl	Effervescent floating system	Antidiabetic	Ranbaxy,India

FUTURE PERSPECTIVES OF GRDDS

One of the biggest problems facing the pharmaceutical business is the GRT of the typical dosage form, particularly for medications that are absorbed from the upper intestine. The disadvantages of the standard dose form will be mitigated by the development of GRDDS, while more research is required to address these issues.

Numerous research on GRDDS, including those on floating, expandable, and mucoadhesive systems, have been conducted to far using the single system approach [39]. Prospects for GRDDS's future appear bright. There are several methods in which GRDDS can enhance medication delivery to the stomach with further study and advancement.

The future perspectives of GRDDS as below followings

- Improved drug bioavailability:
- Extended drug release .
- Targeted drug delivery
- Reduced side effects
- Improved patient compliance.
- Stability
- Biocompatibility
- Manufacturing: GRDDS need to be manufactured in a cost-effective way. This is a challenge, as GRDDS often require specialized equipment and techniques.
- Clinical trials: GRDDS need to be tested in clinical trials to demonstrate their safety and efficacy. This is a long and expensive process, but it is essential to ensure that GRDDS are safe and effective for human use [40-48]

CONCLUSION

Currently, gastro-retentive drug delivery systems are used to improve the bioavailability and controlled distribution of drugs that exhibit an absorption window. During gastro-retentive operations, the main drug delivery techniques that were employed were floating, bio-adhesive, swelling, magnetic, and high density systems. More and more drug delivery systems are being created these days with the goal of releasing the medication into the stomach region. Despite the fact that adopting these medication delivery mechanisms has a number of benefits. From a pharmaceutical point of view, future GRDDS techniques could have to focus on a combined strategy to enhance product quality. The right drug and excipient combinations, formulation methods, and physiological processes that take place in the GIT must all be considered. This review's conclusion included a thorough overview of GRDDS delivery, including their most current developments and commercialized goods.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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