Review Article

Current Approaches on Gastro Retentive Drug Delivery System: An Overview

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ABSTRACT
Gastro retentive drug delivery system (GRDDS) can be defined as a system which remains in the stomach for a sufficient time period and releases active ingredients in a controlled manner. This, significantly extends the duration of drug release, prolongs dosing interval and increases bioavailability of drugs and therefore improves compliance of the patients and effectiveness of pharma cotherapy. The current review deals with the advantages, disadvantages, parameters-affecting gastric emptying, formulation considerations, factors that affect gastro retentive systems and also highlights some of the recent gastro retentive approaches. Recent approaches to increase the gastric residence time of drug delivery systems include bio adhesive systems, floating systems (low density systems), non-floating systems (high density systems) , magnetic systems, swelling systems, un foldable and expandable systems, raft forming systems and superporous systems, biodegradable hydro gel systems. The main emphasis is on the entire classification and different types of GRDDS. Finally evaluation methods of these systems have been summarized.

Key words: *GRDDS, Bioavailability, Gastric emptying, Superporous systems*

INTRODUCTION

Despite tremendous advancements in drug delivery, the oral route remains the preferred route for the administration of therapeutic agents. The low cost of therapy and ease of administration lead to high levels of patient compliances.[1,2]Controlled-release drug delivery systems (CRDDS) provide drug release at a predetermined and predictable rate.[3,4] An important requisite for the successful performance of oral CRDDS is that the drug should have good absorption throughout the gastrointestinal tract (GIT).[5] Conventional oral dosage form provides specific drug concentration in systemic circulation without offering any control over drug delivery and also great fluctuations in plasma drug levels.[6]Gastro retentive drug delivery system (GRDDS) is an approach to prolong gastric residence time, thereby targeting site-specific drug release in the upper gastrointestinal tract (GIT) for local or systemic effects[7] and it is beneficial for improving the bioavailability and therapeutic efficacy of a drug. Drug absorption in the gastrointestinal tract is a highly variable process and it also depends upon the factors such as gastric emptying process, gastrointestinal transit time of dosage forms, drug release from the dosage form, and site of absorption of drugs. [8]The ability to prolong and control the emptying time which reside in the stomach for a longer period of time than conventional dosage forms is a valuable asset for dosage forms. [9] The major problem is the physiological variability such as gastrointestinal transit in addition to gastric retention time and also plays a dominating role in the overall transit of the dosage form. [10] A major constraint in oral controlled drug delivery is that not all drug candidates are absorbed uniformly throughout the GIT and some drugs are absorbed in a particular portion of the GIT only or are absorbed to a different extent in various segments of the GIT. [11] A drug must be in a solubilized and stable form to successfully cross the biological membrane, and it will experience a pH range from 1 to 8 as it travels through the GIT. Because most drugs are absorbed by passive diffusion of the un-ionized form, the extent of ionization at various pH levels can lead to non-uniform absorption or an absorption window. [12]

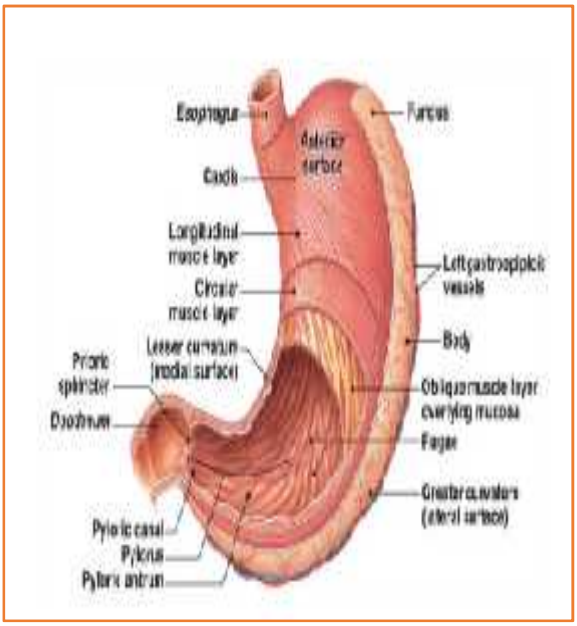

Figure 1: Physiology of Stomach.

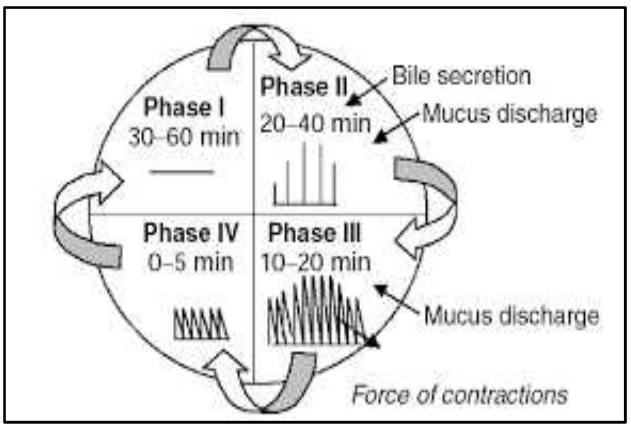

Figure 2: Phases of Gastric Cycle.

Gastrointestinal Tract Physiology

The Gastrointestinal tract is essentially a tube about nine metres long that runs through the middle of the body from the mouth to the anus.[13] The stomach is an organ with a capacity for loading and mixing. In fasting conditions, the stomach is a collapsed bag with a residual volume of nearly 50ml and it contains a small amount of gastric fluid (pH 1–3) as mentioned in table 1. The mucus spreads and covers the mucosal surface of the stomach as well as the rest of the GI tract. [14]Mucus mainly contains water (>95%) and mucin, which are glycoprotein's of exceptionally high molecular weight. Mucin behaves as an anionic polyelectrolyte at neutral pH.[15] The proximal part of stomach is made up of fundus and the body which acts as a reservoir for undigested material. The antrum is the main site for mixing motions and which acts as a pump for gastric emptying by propelling actions. [16]. Gastric emptying process occurs during fasting as well as fed states. During the fasting state an interdigestive series of electrical events take place and which cycle both through the stomach and intestine every 2 to 3 h.[17] This type of condition is called the interdigestive myoelectric cycle or migrating myoelectric cycle (MMC), which is further divided into following 4 phases

Phase I: Phase I is a quiescent period and lasting from 30 to 60 minutes with no contractions.

Phase II: Phase II consists of intermittent contractions that gradually increase in intensity as the phase progresses and it lasts about 20 to 40 minutes.

Phase III: Phase III is a short period of intense distal and proximal gastric contractions (4 to 5 contractions per minute) lasting about 10 to 20 minutes. It is also known as "housekeeper wave" sweep gastric contents down to small intestine.

Phase IV: Phase IV is a short transitory period of about 0 to 5 minutes, and the contractions dissipate between the last part of phase III and quiescence of phase I.

In the fasted-state, the emptying pattern is independent of the presence of any indigestible solids in the stomach. The patterns of contractions in the stomach occur such that solid food is reduced to particles of less than 1mm diameter and which get emptied through the pylorus as a suspension. The duration of the contractions is dependent on the physiochemical characteristics of the ingested meal. [18]

The gastro retention of the dosage forms centred on the following approaches, [18]

- low density of the dosage forms that causes buoyancy in the stomach.
- high density dosage forms which remains at the bottom of the stomach.
- bioadhesion to stomach mucosa.
- slow motility of the GIT.
- expansion by swelling or unfolding which limits emptying of the dosage form.

Requirements For Gastric Retention

The physiological factors in the stomach which includes the gastric retention and the dosage form which must fulfil certain requirements. The main problem in the gastric retention is that the dosage form must be able to withstand the forces caused by peristaltic waves in the stomach, constant contractions, grinding, churning mechanisms and to function as a gastric retention device, it must resist premature gastric emptying [19-25].

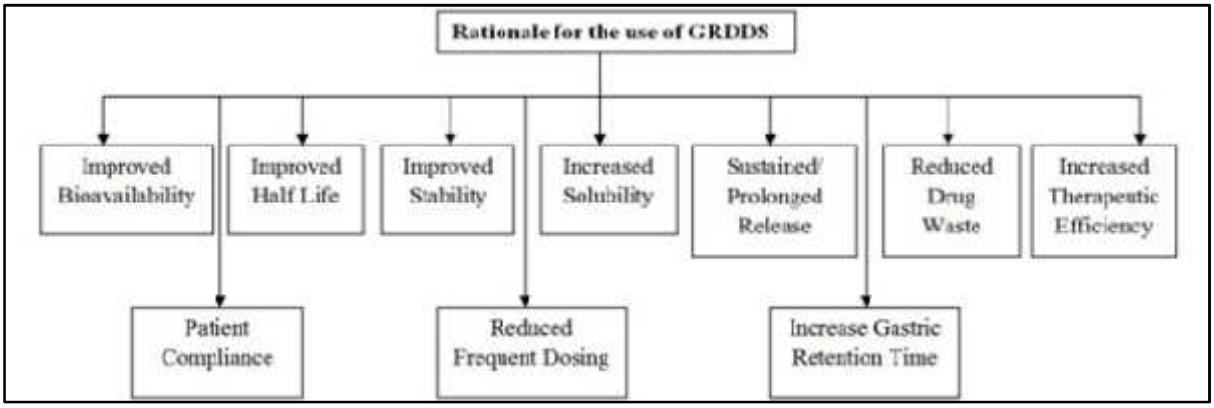

Figure 3: Rationale for the use of GRDDS.

Need For Gastro Retention[26]

Conventional oral delivery is widely used in pharmaceutical field to treat diseases like peptic ulcers caused by H.pylori infection. Gastro-retentive delivery is one of the site specific deliveries for the delivery of drugs either at stomach or at intestine. Drugs used which are less soluble or that degrade at the alkaline pH.The rationale for the use of GRDDS [27]is shown in Figure 3.

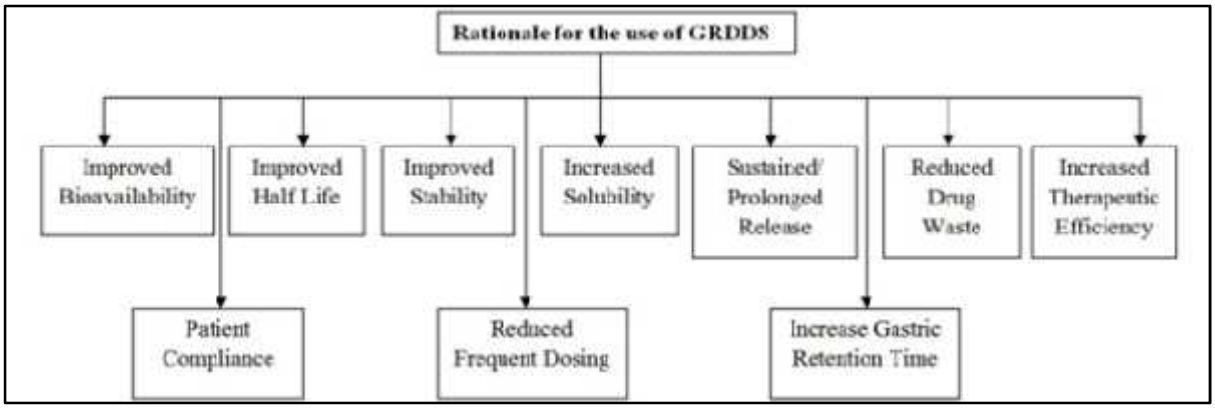

Figure 3:Rationale for the use of GRDDS.

Advantages

GRDDS can produce prolong and sustain release of drugs from dosage forms which aim to the local therapy in the stomach and small intestine. Excellent accessibility and rapid absorption because of enormous blood supply and good blood flow rates.[28]The retention of dosage form in the stomach for an extended period of time. It improves the pharmacotherapy of stomach through local drug release. The drugs which improve the solubility are less soluble in a high pH environment. Delivery of drugs with narrow absorption windows in the small intestinal region can be used.[29]

Disadvantages [29]

1. It is not suitable for the drugs that cause gastric irritation and have solubility problem in gastric fluid. The drugs that are unstable in gastric environment cannot be used. It requires a high level of fluid in the stomach so that the dosage form must float and work. Drugs with colonic release are not suitable for this type of delivery systems. High density system can also be waived out during the house keeping waves (Phase III).

Factors Controlling Gastric Retention Of Dosage Forms[30-33]

1. **Nature of meal**: Feeding of indigestible polymers or fatty acid salts can change the motility pattern of the stomach to that of the fed state and thus, decreasing the gastric emptying rate of the stomach and prolonging drug release.
2. **Caloric content**: GRT can be increased by 4 to 10 h with a meal i.e. high in proteins and fats.
3. **Density:** GRT is a function of dosage form buoyancy that is dependent on the density and the dosage form also affects the gastric emptying rate. The dosage forms having a density lower than the gastric contents can float to the surface, while the high density systems sink to bottom of the stomach and the density of < 1.0 gm/ cm^3 is required to exhibit floating property of the dosage form.
4. **Size and Shape of dosage form:** Shape and size of the dosage forms are important in designing indigestible single unit solid dosage forms. In most cases, the larger the dosage form the greater will be the gastric due to the larger size of the dosage form would not allow this to quickly pass through the pyloric antrum into the intestine. Ring-shaped and tetrahedron-shaped devices have a better gastric residence time as compared with other shapes.
5. **Food intake and its nature**: Food intake, viscosity and volume of food, caloric value and frequency of serving and have a deep effect on the gastric retention of dosage forms. The presence or absence of food in the GIT influences the gastric retention time (GRT) of the dosage form and thus, the drugs absorption increases by allowing it to stay at the absorption site for a longer period of time. Again, increase in acidity and caloric value shows down gastric emptying time (GET), which can improve the gastric retention of dosage forms.
6. **Effect of gender, posture and age**: The gastric emptying rate is less in female as compared to male. The effect of posture does not have any significant difference in the mean gastric retention time (GRT) for individuals and supine state condition. In case of elderly persons, gastric emptying is slowed down.

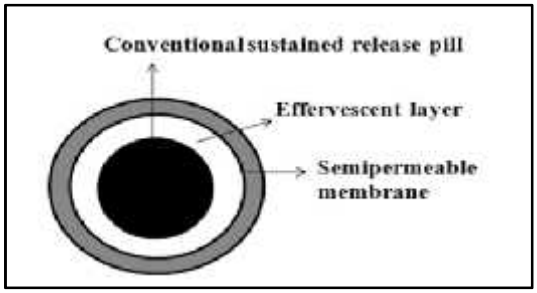

Figure 4: Drug release from effervescent system.

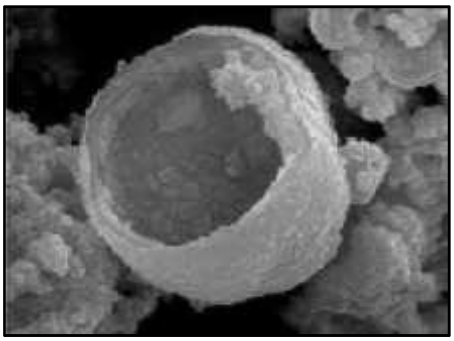

Figure 5: Micro balloon.

Potential Drug Candidates For Grdds

Drugs acting locally in the stomach, e.g. Antacids and drugs Pylori viz., Misoprostol. [34,35]

Drug that is poorly soluble at alkaline pH e.g. Furosemide.[36]

Drug that are used to degrade or unstable in colon. E.g. Ranitidine HCl[37], Metronidazole[38]

Drugs unstable in the lower part of GIT, e.g., Captopril.[39]

Drugs insoluble in intestinal fluids, e.g., Quinidine, Diazepam.[40]

Drugs that disturb normal colonic bacteria, e.g., Amoxicillin tirhydrate.[41]

Drugs that have narrow absorption window in stomach or upper parts of the small intestine e.g., Riboflavine-5-phosphate[42], Ofloxacin[43], Norfloxacin[44], Domperidone.[45]

Comparison Between Conventional And Gastro Retentive Drug Delivery Systems [46, 47]

Conventional Drug Delivery System	Gastro Retentive Drug Delivery System
More side effect	No risk of dose dumping
Patient compliance is less	Improves patient compliance
Less gastric retention time	Improves gastric retention time
Not appropriate for delivery of drugs with narrow absorption window in small intestine region	Appropriate for delivery of drugs with narrow absorption window in small intestine region
Not beneficial for drugs exhibit local action in stomach and degrade in the colon having rapid absorption through GIT	Beneficial for drugs exhibit local action in stomach and degrade in the colon having rapid absorption through GIT

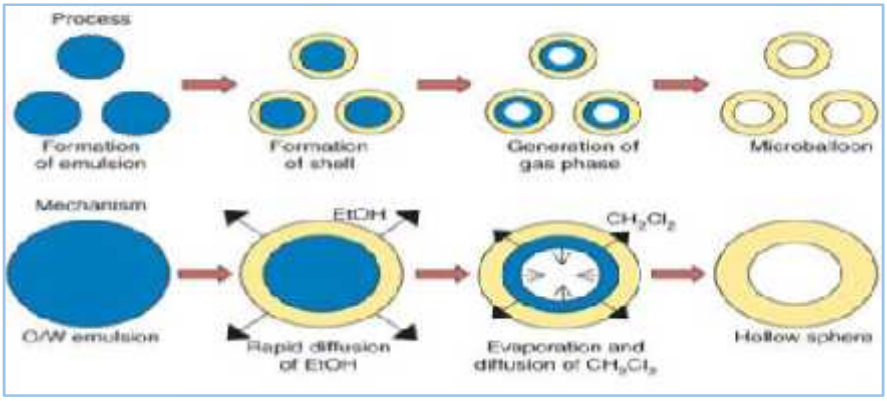

Figure 6: Preparation technique of micro balloon using solvent diffusion method.

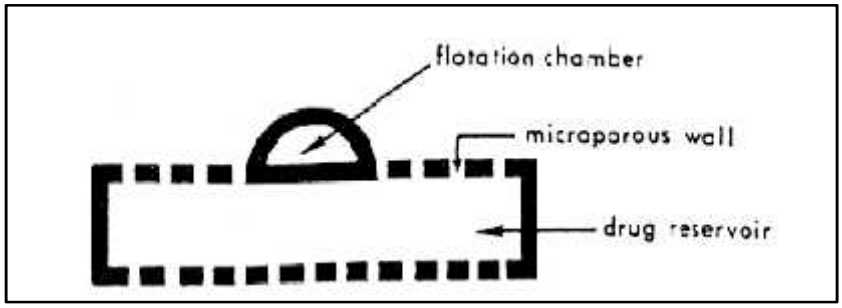

Figure 7: Micro porous Compartment.

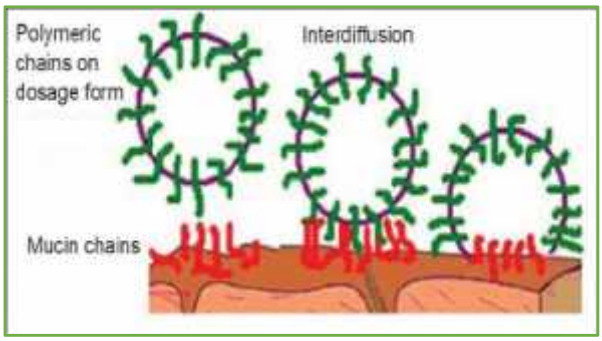

Figure 8: Mechanism of Bioadhesion.

Recent Approaches Of The Grdds

Floating Drug Delivery Systems (FDDS)

Floating drug delivery systems was first described by Davis in 1968. These are low-density systems that have sufficient buoyancy to float over the gastric contents and remain in the stomach for a prolonged period [48] and one of the important approaches to achieve gastric retention and to obtain sufficient drug bioavailability. This system is desirable for drugs with and absorption window in the stomach or in the upper small intestine. [49] FDDS having a bulk density lower than gastric fluids and thus, that remain buoyant in the stomach without affecting the gastric emptying rate for a prolonged period of time. While the system floats over the gastric contents, the drug is released slowly at the desired rate from the system, which results in increased GRT. This results in a better control of fluctuations in the plasma drug concentrations. [50-52]Based on the buoyancy mechanism, FDDS is divided into following ways.

Effervescent system

The effervescent systems utilizes the matrices prepared with different type of swellable polymers such as methocel, polysaccharides like chitosan and effervescent components like sodium bicarbonate, citric acid or tartaric acid.[53]Floatation of a drug delivery system in the stomach can be achieved by incorporating a floating chamber filled with vacuum, air, or an inert gas. [54] This type of drug delivery systems developed effervescent reactions between carbonate/bicarbonate salts and citric/tartaric acid to liberate carbon dioxide and which get entrapped in the gellified hydrocolloid layer of the systems. Thus, it decreases its specific gravity and making it to float. The optimal stoichiometric ratio of citric acid and sodium bicarbonate for gas generation is reported to be 0.76:1.[55] They are formed in a manner that upon contact with gastric contents carbon dioxide is released finally entangling in the swollen hydrocolloids, that makes dosage forms buoyant system. Bilayer or multilayer system has also been designed. [56, 57]Types of effervescent systems are as followsIntra Gastric Single or Bilayer Layer Floating Tablets Floating Capsules Floating System with Ion Exchange Resins Multi-Unit Type Floating Pills

Volatile Liquid containing System

This system comprises of dual chambers having an impermeable, pressure responsive, movable bladder separation and the former chamber has drugs and volatile liquid. It may contain a biodegradable plug which can be made up of polyvinyl alcohol or polyethylene. This plug progressively gets dissolve making the chamber to release the gas and to collapse after a definite duration to allow spontaneous release of the inflatable systems from the stomach. The drug continues to release as the device inflates. [58] There are two chambers in the system first contains the drug and the second chamber contains the volatile liquid. [59]These are classified asInflatable gastrointestinal drug delivery system Intra-gastric osmotically controlled drug delivery system.

Non- effervescent system

Non-effervescent floating drug delivery systems are normally prepared from gel-forming or highly swellable cellulose type hydrocolloids, polysaccharides or matrix forming polymers like polyacrylate, polycarbonate, polystyrene and polymethacrylate.[60,61] The intimate mixing of drug with a gel forming hydrocolloid which results in contact with gastric fluid after oral administration and maintain a relative integrity of shape and a bulk density less than unity within the gastric environment.[62] This type of system are also called as 'plug type system' since they have the tendency to remain lodged near the pyloric sphincter. [63] One of the formulation methods of such type of dosage forms may involves the mixing of the drug with a gel and which get swells when in contact with gastric fluid and attains a bulk density of less than one. [64-66]

Colloidal Gel Barrier System or Hydro dynamically Balanced Systems (HBS)

The hydro dynamically balanced system (HBS) or colloidal gel barrier system was first designed by Sheth and Tossounian. HBS contains drug with gel-forming hydrocolloids meant to remain buoyant on the stomach content. [67] . These are single-unit

dosage form, containing one or more gel-forming hydrophilic polymers. Hydroxypropyl methylcellulose (HPMC), hydroxethyl cellulose (HEC), hydroxypropyl cellulose (HPC), sodium carboxymethyl cellulose (NaCMC), agar, carrageenans or alginic acid are commonly used excipients to develop these systems[68,69] and the matrix forming polymer such as polycarbophil, polyacrylates and polystyrene incorporated either in tablets or in capsules. [70-72]

Hollow microspheres or Micro balloons

Micro balloons / hollow microspheres (Figure 5) loaded with drugs in their other polymer shelf were prepared by simple solvent evaporation or solvent diffusion / evaporation methods (Figure 6) to prolong the gastric retention time (GRT) of the dosage form. The polymers used are polycarbonate, Eudragit S, cellulose acetate, calcium alginate, agar and low methoxylated pectin. Buoyancy and drug release are dependent on quantity of polymer, the plasticizer polymer ratio and the solvent used. [73]

Micro porous Compartment System

This approach is based on the principle of the encapsulation of a drug reservoir inside a micro porous compartment (Figure 7) with pores along its top and bottom walls. [74]The peripheral walls of the drug reservoir compartment are completely sealed to prevent it from direct contact of the gastric mucosal surface with the help of undissolved drug. Gastric fluid enters through the aperture, dissolves the drug, and carries the dissolved drug for continuous transport across the intestine for absorption. [75]

Alginate Beads

The two scientists Talukdar and Fassihi recently developed a multiple-unit floating system based on cross-linked beads and they were made by using Ca_2+ and low methoxylated pectin (anionic polysaccharide) or Ca_2+ low methoxylated pectin and sodium alginate.[76] Spherical beads of almost 2.5 mm in diameter can be prepared by dropping a sodium alginate solution in to aqueous solutions of calcium chloride and it causes precipitation of calcium alginate and multiple unit floating dosage forms have also been developed from freeze-dried calcium alginate. The beads are separated out and then get frozen in liquid nitrogen and after that freeze dried at -40°C for 24 h, leading to the formation of porous system and these beads improve gastric retention time (GRT) more than 5.5 h. [77]

Raft Forming System[78,79]

Floating Rafts have been used in the treatment of Gastric esophageal reflux disease (GERD) and the mechanism involved in the raft formation system which includes the formation of viscous cohesive gel when in contact with gastric fluids. Each portion of the liquid swells and forms a continuous layer called a raft. It has low bulk density because the system ingredients includes a gel forming agent like alkaline bicarbonates or carbonates which is responsible for the formation of CO_2 to make the system less dense. The system contains a gel forming agent (e.g. sodium alginate) which forms a foaming of sodium alginate gel (raft), which when comes in contact with gastric and prevents the reflux of the gastric contents into the oesophagus.

Unfoldable, Swelling, Expanding and Superous Hydrogel Systems

In this type of expandable system, the dosage form in the stomach will withstand gastric transit and however, the dosage form in this system must be small enough to be swallowed, and must not cause gastric obstruction either singly or by accumulation of the drug. [80]Unfoldable systems are made of biodegradable polymers.[81]Swelling and expanding systems are dosage forms that, after swallowing, swell to an extent and exit from the pylorus. As a result in this type of dosage form it get retained in the stomach for a long period of time. Swelling and controlled release of the drug may be achieved in this systems as in contact with gastric fluid. [82] The recent advancement in the field have led to super porous hydrogel hybrids, which are prepared by adding a hydrophilic or water dispersible polymer and that can be cross-linked after the super porous hydrogel is formed and the average pore size is >100 micro meter. Examples of hybrid agents include polysaccharides such as sodium alginate, pectin and chitosan.[83]

High Density (Sinking) Drug Delivery System

In this system the formulations are prepared by coating a drug on a heavy core or mixed with inert materials such as iron powder, barium sulphate, zinc oxide and titanium oxide so that the density of the formulation exceeds to that of the normal gastric content. These systems, which have a density of 3 g/cm^3, are retained in the rugae of the stomach and are capable of withstanding its peristaltic movements. Above a threshold density of 2.4–2.8 g/cm^3, such systems can be retained in the lower part of the stomach. [84]The sedimentation has been employed as a retention mechanism for pellets and which are small enough to be retained in the rugae or folds of the stomach body near the pyloric region. A density close to threshold density seems to be necessary for significant prolongation of gastric residence time. [85-87]

Bioadhesive or Mucoadhesive Systems

Bioadhesive drug delivery systems (BDDS) is a type of drug delivery system which is used as a delivery device within the lumen to enhance drug absorption in a particular site for a specific manner.[88] The term 'mucoadhesion' is commonly used word to describe an interaction between the mucin layer that lines the entire GIT and a bio adhesive polymer.

Bioadhesion can be explained with a number of theories [89,90]

The absorption theory, which suggests that this theory occurs due to two secondary forces i.e. Vander Waal's forces and hydrogen bonding.

The electron theory, which proposes attractive electrostatic forces between two network i.e. the

glycoprotein mucin network and the bio adhesive material (polymer).

The wetting theory, which is based upon the ability of bio adhesive polymers to spread and develop intimate contact with the mucous layers.

The diffusion theory, which proposes physical entanglement of mucin, strands the flexible polymer chains, or an interpenetration of mucin strands into the porous structure of the polymer substrate.

In Vitro Evaluation Of Grdds[91-93]

Bulk density

Bulk density refers that it is the ratio of total mass of powder to the bulk volume of powder and formula for bulk density is as follows

$$B \quad D \quad = \frac{M}{A_j \quad V_i}$$

Tapped density

Tapped density is the ratio of the total mass of the powder to the tapped volume of the powder

$$T \quad D \quad = \frac{M}{T \quad V_i}$$

Carr's Compressibility Index

Carr's Compressibility Index is the ability of powder to decrease in volume under pressure. The formula for Carr's compressibility index is as follows

$$C \quad r^r s \, h \quad = \frac{T \quad D \quad - B \quad D}{T \quad D} x100$$

Hausner's ratio

Hausner's ratio indicates that the flow properties of powder are measured by the ratio of tapped density to that of the bulk density.

$$H \quad r^r s. \quad = \frac{T \quad D}{B \quad D}$$

Angle of repose

The formula for angle of repose is as follows:

$\theta = \tan^{-1}(h/r)$

Here,

h = Height of pile

r = Radius of pile

θ = Angle of repose

Shape and Dimensions of Tablets

Thickness and diameter of the tablet is measured by using a calibrated vernier calliper. And shape is determined visually.

Hardness

The hardness of the tablet indicates that the ability of a tablet to withstand mechanical shocks while handling.

Friability test

The friability of tabletsis determined by using the instrument Friabilator. It is expressed in percentage (%).

Tablet Density

In this the tablet get floats only when its density is less than that of gastric fluid (1.004). The density is determined using following relationship.

$$V = r2hd = \frac{m}{\rho}$$

V = volume of tablet (cc)

r = radius of tablet (cm)

h = crown thickness of tablet (g/cc)

m = mass of tablet

Weight Variation Test

The following percentage deviation in weight variation is allowed as showed in Table 2.

Buoyancy / Floating Lag Time[94]

The time between introduction of dosage form and its buoyancy on the simulated gastric fluid and the time during which the dosage form remain buoyant is measured. The time taken for dosage form to emerge on surface of medium called Floating Lag Time (FLT) or Buoyancy Lag Time (BLT) and total duration of time by which dosage form remain buoyant is called Total Floating Time (TFT).

Swelling Study

Water uptake is measured in terms of percent weight gain, as given by the equation.

$$W_U = \frac{(W \; - W0)}{W} x\ 100$$

W_t = Weight of dosage form at time t.
W_0 = Initial weight of dosage form

Table 1: Anatomical difference between different regions of the GIT

Particulars	Stomach	Small intestine	Large intestine	Rectum
pH range	1-3	5-7.5	7.9-8.0	7.5-8.0
Length (cm)	20	285	110	20
Diameter (cm)	15	2.5	5	2.5
Blood flow(L/min)	0.15	1.0	0.02	-
Transit time (hrs)	1-5	3-6	6-12	6-12

In vitro drug release studies

The test for buoyancy and *in vitro* drug release studies are usually carried out in simulated gastric and intestinal fluids maintained at 37°C. In practice, floating time is determined by using the USP dissolution apparatus containing 900ml of 0.1N HCl as a testing medium maintained at 37°C and the time required to float the dosage form is well-known as floating (or floatation) time.

Determination of the drug content

Drug content is determined by using HPLC, HPTLC methods, Near Infrared Spectroscopy (NIRS), Micro titrimetric methods, Inductively Coupled Plasma Atomic Emission Spectrometer (ICPAES) and also by using spectroscopy techniques.

Fourier Transform Infrared Analysis

Fourier transform infrared spectroscopy is a technique mostly used to identify organic, polymeric, and some inorganic materials as well as for functional group determination.

Differential Scanning Calorimetry (DSC)

DSC is used to characterize water of hydration of pharmaceuticals. Thermo grams of formulated preparations are obtained using DSC instrument equipped with an intercooler. Zinc standards are used to calibrate the DSC temperature and the enthalpy scale.

Table2: Percentage Deviation in Weight

Average Weight of Tablet	Percentage Deviation
130 mg or less	10%
>130mg and <324mg	7.5%
324 mg or more	5%

In Vivo Evaluation Of Grdds [95]

X-Ray method

X-Ray method is a very common evaluation parameter for floating dosage form. It helps to locate dosage form in the GIT and by which one can expect and correlate the gastric emptying time of the dosage form in the GIT. Here, the presence of a radio-opaque material into a solid dosage form enables it to be visualized by X-rays.

Gamma Scintigraphy

Gamma emitting radioisotopes compounded into controlled release dosage forms has become the state-of-art for estimation of gastro retentive formulation in healthy volunteers. The main drawbacks of gamma scintigraphy are the associated ionizing radiation for the patient, the limited topographic information and expensive preparation of radiopharmaceuticals.

Gastroscopy

It is suggested that gastroscopy may be used to examine the effect of prolonged stay of GRDDS in stomach environment. Alternatively, GRDDS may be drawn out of the stomach for more detailed evaluation of the formulations.

Formulation considerations for GRDDS[96,97]

It should have sufficient drug loading capacity
It should control the drug release profile
It should have full degradation and evacuation of the system once the drug release is over
It should not have effect on gastric motility including emptying pattern
It should not have other local adverse effects

Applications of GRDDS [98]

Gastro retentive drug delivery offers several applications for drugs having poor bioavailability because of the narrow absorption window in the upper part of the git.

Sustained Drug Delivery

HBS systems can remain in the stomach for long periods and hence can release the drug over a prolonged period of time. The problem of short

gastric residence time encountered with an oral CR formulation hence can be overcome with these systems. These systems have a bulk density of 1 as a result of which they can float on the gastric contents. The sustained release floating capsules of nicardipine hydrochloride compared with commercially available MICARD capsules using rabbits. Plasma concentration time curves showed a longer duration for administration (16 hours) in the sustained release floating capsules as compared with conventional MICARD capsules (8 hours).

Site-Specific Drug Delivery

These systems are particularly advantageous for drugs that are specifically absorbed from stomach or the proximal part of the small intestine, eg, furosemide. It has been reported that a monolithic floating dosage form with prolonged gastric residence time was developed and the bioavailability was increased. AUC obtained with the floating tablets was approximately 1.8 times those of conventional furosemide tablets.

Absorption Enhancement

Drugs that have poor bioavailability because of site specific absorption from the upper part of the gastrointestinal tract are potential candidates to be formulated as floating drug delivery systems, thereby maximizing their absorption. A significant increase in the bioavailability of floating dosage forms (42.9%) could be achieved as compared with commercially available LASIX tablets (33.4%) and enteric coated LASIX-long product (29.5%).

Conclusion And Future Potential [99]

GRDDS have emerged as current advances of enhancing bioavailability and controlled delivery of drugs that exhibit an absorption window. GRDDS approaches comprised mainly of floating, bio adhesive, swelling, magnetic, and high density systems. These systems provide controlled release of the drug along with the presentation of the drug in an absorbable form at the regions of optimal absorption. All these drug delivery systems have their own advantages and drawbacks. To design a successful GRDDS, it is necessary to take into consideration the physicochemical properties of the drug, physio logicalactions in the GIT, formulation approaches and correct combination of drug and additives. Floating dosage form offers various future potential as evident from several publications i.e. the reduced fluctuation in the plasma level of drug results from delayed gastric emptying. Drugs that have poor bioavailability because of their limited absorption to the upper GIT can be delivered efficiently and thus maximizing their absorption and improving their absolute bioavailability. Buoyant delivery system considered as a beneficial strategy for the treatment of gastric and duodenal cancers. The floating concept can also be utilized in the development of various anti-reflux formulation. Developing a controlled release system for the drugs, which are potential to treat the Parkinson's disease. To explore the eradication of Helicobacter pylori by using the narrow spectrum antibodies.

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