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Review on: - Osmotic Drug Delivery System: A Emerging Trend in Drug Delivery System

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ABSTRACT
The secret to successful pharmaceutical research and development is a novel medication delivery method. The release of a drug over a long period of time can be modulated or altered using a number of conventional drug delivery techniques. Osmotic drug delivery system (ODDS) uses the fundamental osmotic pressure principle for regulated medication release. In order to minimise side effects and keep drug concentration within the therapeutic window. This review focuses on the theoretical idea of drug delivery, the fundamentals and different kinds of osmotic drug delivery systems, as well as the benefits and drawbacks of each. Keywords: novel drug delivery system, controlled formulation, osmotic pump, osmosis, and osmotic drug delivery system.

I. INTRODUCTION

The creation of innovative drug delivery systems (NDDS) has received a lot of interest in recent months. The form of NDDS known as an osmotically regulated drug delivery system (ODDS) uses osmotic pressure to deliver an active ingredient under control. stomach pH and stomach motility have little impact on the release of drugs from the osmotic system. However, pH, GI motility, and the presence of food in the GI tract can all have an impact on drug release from oral controlled release dosage forms3. One of the most promising drug delivery technologies, osmotically controlled drug delivery systems (OCDDS), uses osmotic pressure as a driving mechanism for regulated distribution of active drugs. Because OCDDS is semi-permeable, drug release is unaffected by the body's hydrodynamic and pH conditionsOsmosis is the process of moving a solvent over a semipermeable membrane from a solute with a lower concentration to one with a greater concentration. Osmotic pressure is the least amount of pressure that must be applied to a solution in order to block the passage of the solution's pure solvent through a semipermeable membrane. The osmotic pressure difference between the inside and exterior of the semipermeable membrane acts as the drug delivery power in the innovative drug delivery method known as the osmotic pump controlled release preparation. Osmotic tablets have been produced recently, and the delivery hole is created by adding a leachable substance to the coating. The water-soluble component of the pill dissolves as it comes into touch with the aquatic environment, and Subsequently, water diffuses into the core through the micro porous membrane, setting up an osmotic gradient and thereby controlling the release of drug. Osmosis is the spontaneous movement of a solvent through an ideal semipermeable membrane, which is permeable only to the solvent but impermeable to the solute, from a solution of lower solute concentration to a solution of higher solute concentration. The osmotic pressure is the force provided to the side with higher concentrations to prevent solvent flow. Osmotic tablets have recently been created, and the delivery hole is created by adding a leachable substance to the coating. The water-solvent component of the tablet separates as it comes into contact with the fluid environment, creating an osmotic syphoning framework. Water then diffuses into the core through the tiny pores in the membrane, creating an osmotic gradient that regulates the release of the medicine. Osmosis is the spontaneous movement of a solvent through an ideal semipermeable membrane, which is permeable only to the solvent but impermeable to the solute, from a solution of lower solute concentration to a solution of higher solute concentration. The osmotic pressure is the force provided to the side with higher concentrations to prevent solvent flow.

Advantage of Osmotic drug delivery system: Osmotic drug delivery systems for oral use offer distinct and practical advantages over other means of delivery. The following advantages have contributed to the popularity of osmotic drug delivery systems:

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

1. They typically provide a zero-order release profile after an initial lag. This means that the drug is released at a constant rate over time, providing a steady and predictable release of medication.
2. The release mechanisms are independent of drug concentration. This ensures that the drug is released at a consistent rate regardless of the concentration of the drug in the system, which helps to maintain a steady therapeutic effect.
3. Osmotic drug delivery systems can provide sustained and consistent blood levels within the therapeutic window, which helps to improve patient outcomes and reduce the risk of adverse effects.
4. Osmotic drug delivery systems can help to reduce side effects by delivering medication at a steady rate, rather than in large or uneven doses. This can help to minimize the risk of side effects associated with fluctuating drug levels.
5. Osmotic drug delivery systems can be designed to deliver medication with a delayed or pulsed release, allowing for more flexible dosing schedules.
6. Drug release from osmotic drug delivery systems is not affected by changes in gastric pH or hydrodynamic conditions in the gastrointestinal tract, which helps to ensure consistent drug delivery.
7. Osmotic drug delivery systems are well-characterized and widely understood, which facilitates their development and regulatory approval.
8. The delivery rate of osmotic drug delivery systems is not affected by agitation outside the body, including gastrointestinal motility.
9. Osmotic drug delivery systems can enhance the bioavailability of certain drugs, leading to improved therapeutic outcomes.
10. Osmotic drug delivery systems can help to reduce interpatient variability in drug response and dosing requirements.
11. The release rate of drugs from osmotic drug delivery systems is highly predictable and can be programmed to meet specific therapeutic needs.
12. Osmotic drug delivery systems can reduce dosing frequency, which can improve patient adherence to medication regimens.
13. Improved patient compliance is a benefit of osmotic drug delivery systems, which can lead to better treatment outcomes.
14. Osmotic drug delivery systems can increase the safety margin of high-potency drugs, reducing the risk of adverse effects.
15. Drug release from osmotic drug delivery systems exhibits significant in vitro-in vivo correlation (IVIVC) within specific limits, which can help to predict drug behavior in the body.
16. Osmotic drug delivery systems can provide better release rates than those achieved with conventional diffusion-based drug delivery systems.

Disadvantage:

- Osmotic drug delivery systems can be expensive compared to other drug delivery methods.
- Poorly controlled coating processes can result in film defects, which can cause dose dumping and compromise drug efficacy.
- Inelemetric osmotic systems, the size of the holes in the membrane is critical for drug release, and if not well-controlled, can affect the performance of the system.
- Drug release from osmotic systems can be affected by the presence of food in the gastrointestinal tract.
- Once an osmotic drug delivery system is ingested, it is not possible to retrieve or reverse the therapy in the event of an unexpected adverse event.
- There is a risk of the rapid development of tolerance with some drugs delivered via osmotic drug delivery systems, which can compromise treatment efficacy over time

Historical Background:

The osmosis principle was first applied to drug delivery systems by Rose and Nelson in 1955, when they designed an implantable pump with three chambers: a drug chamber, a salt chamber containing excess solid salt, and a water chamber. The first osmotic drug delivery system was developed by Theeuwes in 1974, as per Vincent et al. (2009). In 1975, Theeuwes simplified the Rose-Nelson pump and created a system known as the elementary osmotic pump (EOP), which was patented and marketed by Alza Corporation in the USA, and has been used to deliver various drugs. Higuchi and Theeuwes also developed a simplified variant of the Rose-Nelson pump. The elementary osmotic pump (EOP) was designed by Higuchi and Leeper in 1973. It consisted of a tablet-core surrounded by a semipermeable membrane with a single passageway or orifice. The first two products

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

based on the EOP concept were indomethacin (Osmosin) and phenylpropanolamine (Acutrim TM), which were launched in the 1980s. However, Osmosin had to be withdrawn from the market due to severe side effects such as gastrointestinal irritation and perforation of the intestinal wall.

The controlled-porosity osmotic pump (CPOP) was developed as an oral drug delivery system by Zentner et al. (1985, 1991), Zentner and Rork (1990), Appel and Zentner (1991), and McCelland et al. (1991). The CPOP was designed to decrease the risk of extremely localized drug-induced irritation at the site close to the orifice, as seen in the case of Osmosin. The push-pull osmotic pump (PPOP) was also developed to target the applicability of the OODS to poorly soluble drugs.

Nifedipine PPOP (Procardia XL) was one of the most successful drug delivery systems of the last century, marking the revival of the OODS.

PRINCIPLES OF OSMOTIC DRUG DELIVERY SYSTEM:

Principles of osmosis: The phenomenon of osmosis has been extensively studied by scientists and is used in multiple branches of science and engineering. The idea of osmosis was first developed by humans when they recognized that salt could be used to dehydrate foodstuffs, allowing them to be stored for longer periods of time. It was observed that when a salty environment is present around food, bacteria, fungi, and other microorganisms become dried up and are disabled or sometimes die due to osmosis. Natural materials were used to study osmosis before the 1960s, but synthetic materials have been used since then. Osmosis is defined as the mobility of water through a selectively-permeable membrane, which occurs due to a difference in osmotic pressure across the membrane. The selective membrane only allows the route for water, but does not permit the movement of solute molecules or ions. The environment of the gut does not affect the phenomenon of osmosis, and drug delivery can be easily assumed from the characteristics of the drug and its dosage form. The pressure that prevents the flow of solvent to a high concentration is called the osmotic pressure. The osmotic phenomenon was first reported by Abbe Nollet in 1748, and later Pfeffer separated sugar solution from pure water using a selectively permeable membrane. The osmotic pressure exhibited by the sugar solution was directly proportional to the amount and temperature of the solution. This proportionality was expressed by Vant Hoff in 1886 in the form of an equation: $\pi = n2\ RT$, where π is the osmotic coefficient and n2 is the molar concentration of solute in the solution.

1.3. **Types of Osmotically Controlled Drug Delivery Syst**

1**. Single chamber osmotic system**:

1.1. Elementary osmotic pump

2. **Multi chambered osmotic pumps**

1.3.2.1. Push-pull osmotic pumps

1.3.2.2. Sandwiched osmotic pump

1.3.2.3. Osmotic pump with non expanding second chamber

3. **Specific types**

1.3.3.1. Controlled-porosity osmotic pumps

1.3.3.2. Monolithic osmotic pumps tablet

1.3.3.3. Colon targeted Oral Osmotic System (Oros CT)

1.3.3.4. Osmotically Brusting Osmotic Pump

1.3.3.5. Asymmetrical Membrane Osmotic Tablet

1.3.3.6. Liquid Oral Osmotic System

1.3.3.7. Effervescent Osmotic pump Tablet

1.3.3.8. Multiparticulate Delayed-Release System (osmotic pellet)

1.3.3.9. Self Emulsified Osmotic Tablet

1.3.3.10. Telescopic capsule for Delayed-Release

1.3.1. Single chamber osmotic system:

Single chamber osmotic pump:

The elementary osmotic pump (EOP) is a novel drug delivery system that delivers the active agent at a controlled rate through an osmotic process. The semi-permeable membrane surrounding the formulating agent and the osmotic properties of the formulation control the drug delivery rate. The tablet contains an osmotic core with the drug surrounded by a semi-permeable membrane with a delivery orifice. When water enters the system after ingestion, it dissolves the drug, and the resulting drug solution is delivered at the same rate as the water entering the tablet through osmosis. This displaces the drug in the core, which is then released from the orifice. However, the EOP has limitations as it is only suitable for water-soluble drugs. One of the advantages of this system is its ability to allow zero-order delivery of the drug.

International Journal of Pharmaceutical Research and Applications
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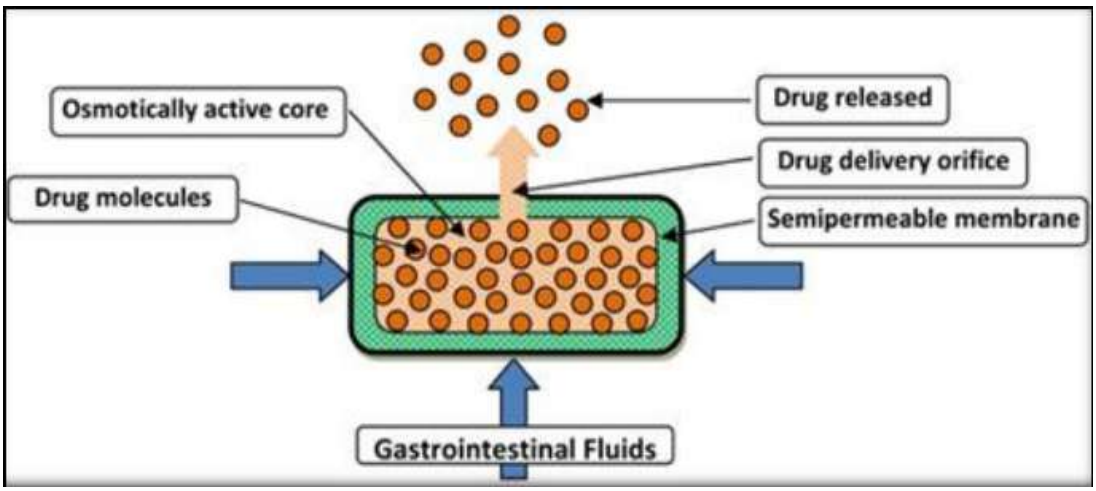
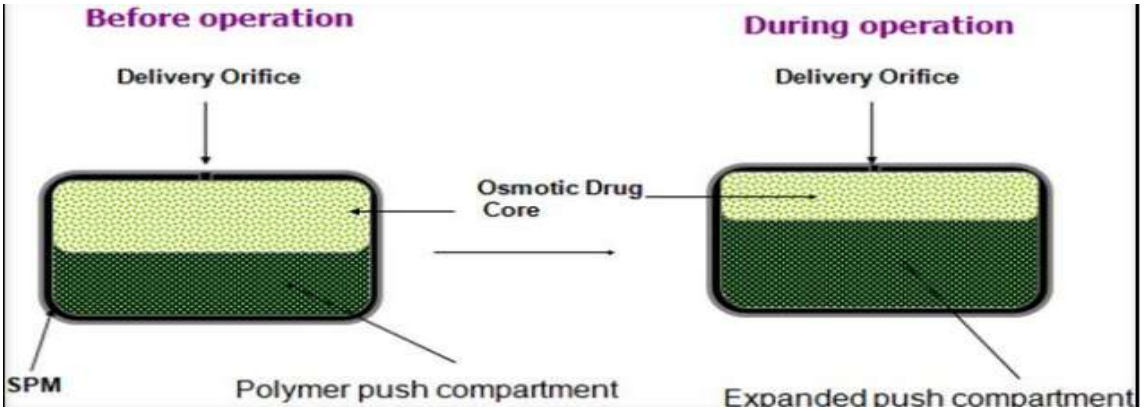


Push pull osmotic pump:

This is a description of the Osmotic Controlled Release Oral Delivery System, which is a type of osmotic pump tablet. It is composed of two layers - an upper layer containing the drug osmogent, and a lower layer containing a polymeric osmotic agent. The tablet is coated with a semipermeable membrane and has a delivery orifice drilled on the drug side. When the tablet comes into contact with gastric fluids, water enters the tablet and causes the polymeric osmotic layer to swell. This swelling pushes the drug layer through the orifice, delivering the drug in the form of a fine dispersion. Like other osmotic pump tablets, this system allows for zero-order delivery of the drug.



Osmotic pump with non- expanding second chamber:

In this case there will be no expansion of second chamber and based on the functioning of this chamber, they are of two types. In the firstOsmotic pump with non- expanding second chamber: In this case there will be no expansion of second chamber and based on the functioning of this chamber, they are of two types.

Specific types:

Controlled porosity osmotic pump:

It is an osmotic device wherein the delivery orifices are formed in situ through leaching of water soluble pore-forming agents incorporated in semipermeable membrane (E.g., urea, nicotinamide, sorbitol, etc.). Drug release rate from controlled porosity osmotic pump depends on various factors like coating thickness, level of leachable pore-forming agent(s) solubility of drug in tablet core, and the osmotic pressure difference across the membrane. There are several advantages characteristic to the system. The stomach irritation problems are significantly reduced, as drug is released from the whole of the device surface rather from a single hole. Further, no complicated laser-drilling unit is required because the delivery orifices are formed in situ.

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

Osmotic bursting osmotic pump:

This system is similar to an elementary osmotic pump expect delivery orifice is absent and size may be smaller. When it is placed in an gastric fluids, water is imbibed and hydraulic pressure is built up inside until the semipermeable membrane rupture and the content are released to the environment. Varying the thickness as well as the area the semipermeable membrane can control release of drug. This system is useful to provide pulsated

Liquid Oral Osmotic system:

This device is designed to deliver liquid drug formulations, which are particularly useful for delivering insoluble drugs and macromolecules such as polysaccharides and polypeptides. The device consists of three layers: a rate-controlling membrane, an osmotic layer, and a soft gelatin capsule. When the device is ingested, water permeates across the rate-controlling membrane and causes the osmotic layer to expand, creating hydrostatic pressure inside the system. This pressure forces the liquid formulation out of the delivery orifice. The device provides several advantages, such as protection of the drug from enzymatic degradation and promotion of gastrointestinal absorption.

Delayed Delivery Osmotic device:

Because of semi permeable walls, an osmotic device integrally show lag time before drug delivery begins. Although this characteristic is usually cited as a drawback, it can be used advantageously. The delayed release of certain drug (drugs for early morning asthma or arthritis) may be beneficial.

Telescopic Capsule for Delayed Release:

This device is known as an osmotic capsule, and it consists of two chambers, one for the drug and the other for an osmotic engine. The two chambers are separated by a wax-like material, and the device has an exit port for drug delivery. To assemble the device, the drug is placed into one of the chambers, and the osmotic bilayer tablet is placed into the completed cap part of the capsule with the convex osmotic layer pointed into the closed end of the cap and the barrier layer exposed towards the cap opening. The open end of the filled vessel is then fitted inside the open end of the cap, and the two pieces are compressed together until they fit tightly.

When fluid enters the device, the osmotic engine expands and exerts pressure on the two wall sections, which are slid-able and connected. During the delay period, the volume of the reservoir containing the active agent remains constant, and a negligible pressure gradient exists between the environment of use and the interior of the reservoir. As a result, the flow of environmental fluid driven by the pressure entering the reservoir is minimal, and no agent is delivered during this period. This delay period can be advantageous for drugs that require a delayed release, such as those used to treat early morning asthma or arthritis.

Oros Colon Targeting:

This system is designed for targeted drug delivery to the colon, usually taken once or twice a day. It can be a single osmotic agent or a combination of several push-pull osmotic units contained in a hard gelatin capsule. Upon contact with an aqueous environment, the gelatin capsule dissolves, and the enteric coating prevents entry of fluids from the stomach into the system. When the system enters the small intestine, the enteric coating dissolves, and water is imbibed into the core, causing the push compartment to swell. This leads to the formation of a flowable gel in the drug compartment, which is then pushed out of the orifice at a controlled rate determined by the rate of water transport across the semipermeable membrane.

Another type of osmotic system is the sandwiched oral therapeutic system, which consists of a tablet core made up of a polymeric push layer sandwiched between two drug layers with two delivery orifices. When the device is placed in an aqueous environment, the middle push layer containing the swelling agent swells, and the drug is released from the two orifices situated on opposite sides of the tablet. This type of system can be suitable for drugs that are prone to cause local irritation of the gastric mucosa.

Monolithic osmotic system:

This system is called a matrix system, where a water-soluble drug is dispersed within a polymer matrix. When the system comes into contact with an aqueous environment, water penetrates the polymer matrix, causing the drug to be released from the polymer matrix. Initially, this process occurs at the outer surface of the matrix, but it gradually progresses towards the interior of the matrix. However, if more than 20-30 volumes per liter of the active agent are incorporated into

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

the device, significant contribution from the simple leaching of the substance may occur, and the system may fail.

BASIC COMPONENTS OF OSMOTIC SYSTEMS

Drug;

Drugs with a short biological half-life and those used for prolonged treatment are ideal candidates for osmotic systems. Various drugs, such as Diltiazem HCl, Carbamazepine, Metoprolol, Oxprenolol, and more, have been formulated as osmotic delivery systems.

Semi-permeable membrane;

The selection of the semi-permeable membrane housing is an important aspect of osmotic drug delivery systems. The membrane should possess certain characteristics, such as impermeability to the passage of the drug and other ingredients present in the compartments. The membrane should be inert and maintain its dimensional integrity to provide a constant osmotic driving force during drug delivery. Any polymer that is permeable to water but impermeable to solute can be used as a coating material in osmotic devices. Examples include cellulose esters such as cellulose acetate, cellulose acetate butyrate, cellulose triacetate, and ethyl cellulose, as well as Eudragits.

29 Flux regulators;

Delivery systems can be designed to regulate the permeability of the fluid by incorporating flux-regulating agents in the layer. Hydrophilic substances such as polyethylene glycols (with molecular weights ranging from 300 to 6000 Da), polyhydric alcohols, polyalkylene glycols, and the like improve the flux, whereas hydrophobic materials such as phthalates substituted with an alkyl or alkoxy group (e.g., diethyl phthalate or dimethoxy ethylphthalate) tend to decrease the flux. Insoluble salts or oxides, which are substantially water-impermeable materials, can also be used for this purpose.

30 Coating solvent;

Solvents suitable for making the polymeric solution used for manufacturing the wall of the osmotic device include inert inorganic and organic solvents that do not adversely affect the core, wall, and other materials. Examples of typical solvents include methylene chloride, acetone, methanol, ethanol, isopropyl alcohol, butyl alcohol, ethyl acetate, cyclohexane, carbon tetrachloride, and water. Mixtures of solvents, such as acetone-methanol (80:20), acetone-ethanol (80:20), acetone-water (90:10), methylene chloride-methanol (79:21), and methylene chloride-methanol-water (75:22:3), can also be used.

31 Wicking agent;

A wicking agent can be either swellable or non-swellable, and is characterized by its ability to undergo physiosorption with water, which is a form of absorption in which solvent molecules loosely adhere to the surface of the wicking agent via Van der Waals interactions. The function of the wicking agent is to carry water to surfaces inside the core of the tablet, thereby creating channels or a network of increased surface area. Materials suitable for acting as wicking agents include colloidal silicon dioxide, kaolin, titanium dioxide, alumina, niacinamide, sodium lauryl sulfate (SLS), low-molecular-weight polyvinylpyrrolidone (PVP), m-pyrol, bentonite, magnesium aluminum silicate, polyester, and polyethylene. SLS, colloidal silica, and PVP are non-swellable wicking agents.

32 Pore forming agent;

The pore-forming agents cause the formation of a micro-porous membrane. The micro-porous wall may be formed in situ by a pore-former by its leaching during the operation of the system. The pore-formers can be inorganic or organic, and solid or liquid in nature. For example, alkaline metal salts such as sodium chloride, sodium bromide, potassium chloride, potassium sulphate, potassium phosphate, etc., alkaline earth metals such as calcium chloride and calcium nitrate, carbohydrates such as sucrose, glucose, fructose, mannose, lactose, sorbitol, and mannitol, and diols and polyols such as polyhydric alcohols, polyethylene glycols, and polyvinyl pyrrolidone can be used as pore-forming agents.

Different types and amounts of plasticizers used in coating membranes also have significant importance in the formulation of osmotic systems. They can change the viscoelastic behavior of polymers, and these changes may affect the permeability of the polymeric films. Some of the plasticizers used are as follows:

- Polyethylene glycols
- Ethylene glycol monoacetate
- Diacetate- for low permeability
- Tri ethyl citrate

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

• Diethyl tartarate or Diacetin- for more permeable film

Osmotic agent;

These are also known as osmogents and are used to create osmotic pressure inside the system. When the solubility of drug is low then the drug will show zero order release but at a slow rate. To enhance the release rate osmotic agent is added in the formulation. Osmotic agent creates a very high osmotic pressure gradient inside the system and increases release rate of drug.

Some of the commercially used osmotic agents;
Sodium chloride, Fructose, Sucrose, Potassium chloride, Xylitol, Sorbitol, Citric acid, Dextrose, Mannitol and Lactose.

Some Mixture Used As an Osmotic Agent;
Dextrose +Fructose
Lactose +Fructose36
Sucrose+ Fructose
Lactose +Dextrose
Mannitol +Fructose
Mannitol +Dextrose
Dextrose +Sucrose
Mannitol +Sucrose

KEY PARAMETERS FOR DESIGNING OF OSMOTIC DRUG DELIVERY SYSTEMS:
OSMOTIC PRESSURE

Osmotic pressure is dependent on the number of solute particles present in a solution. The release rate of a drug from an osmotic system is directly proportional to the osmotic pressure. To control drug release from these systems, it is important to optimize the osmotic pressure gradient between the interior compartment and the external environment. A constant osmotic pressure can be maintained by keeping the osmotic agent solution in the core compartment. If a drug lacks sufficient osmotic pressure, an osmotically active agent can be added to the formulation.

Polymeric cosolvents are primarily used in the manufacture of OROS and other modified-release devices for the controlled release of drugs with poor water solubility. These swellable, hydrophilic polymers interact with aqueous fluids and swell or expand to an equilibrium state, retaining a significant portion of the imbibed water within the polymer structure.

DELIVERY ORIFICE

To achieve an optimal zero order delivery profile, the cross-sectional area of the orifice should be smaller than a maximum size to minimize drug delivery by diffusion through the orifice. Furthermore, the area should be sufficiently large, above a minimum size to minimize hydrostatic pressure build up in the system. The typical orifice size in the osmotic pumps ranges from 600µm to 1 mm

Evaluation
Pre Compression Parameters
Bulk density

Bulk density is a measure of the mass of a powder per unit volume of the powder when it is in a loose or unconsolidated state. It is calculated by dividing the mass of the powder by the bulk volume of the powder. The bulk density is influenced by factors such as particle size distribution, shape, and cohesiveness of particles.
To determine the bulk density of a powder, a accurately weighed quantity of powder is carefully poured into a graduated measuring cylinder through a large funnel. The volume of the powder is measured, which is called the initial bulk volume. The bulk density is then expressed in gm/cc and is given by the formula:
Db = M / Vo
where Db is the bulk density (gm/cc), M is the mass of the powder (g), and Vo is the bulk volume of the powder (cc).

B. Tapped density

The measuring cylinder containing a known mass of granules blend is tapped 100 times from a constant height, and the tapped volume is read. The tapped density is the ratio of the mass of the granules blend to the tapped volume. It is expressed in gm/cc and is given by Dt = M / Vt, where Dt is the tapped density (gm/cc), M is the mass of granules blend (g), and Vt is the tapped volume (cc).

C. Compressibility index:

Compressibility index determines the flow property characteristics of granules developed by carr.
The compressibility of the powder was determined by Carr's compressibility index. Carr's index (%) = b=(v/b) X100

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

Sr.no	Carr's Index	Flow Properties
1	5-15	Excellent
2	12-15	Good
3	18-21	Fair to Passable
4	23-30	Poor
5	33-38	Very poor
6	>40	Very Very poor

D. Hausner ratio:

Hausner's ratio is used for the determination of flow properties of granules.

Hausner's ratio = tapped density/bulk density

Values of Hausner ratio; < 1.25: good flow >1.25: poor flow

If the Hausner ratio is between 1.25-1.5,flow can be improved by the addition of glidants.

E. Angle of repose (θ):

The angle of repose is a measure of the flowability of a powder or granular material. It is defined as the maximum angle possible between the surface of the pile of the powder and the horizontal plane. The fixed funnel method is commonly used to measure the angle of repose. In this method, a funnel is fixed with its tip at a given height (h) above a flat horizontal surface on which a graph paper is placed. The powder is carefully poured through the funnel until the apex of the conical pile just touches the tip of the funnel. The angle of repose is then calculated using the formula:

$\tan\theta = h/r$

where θ is the angle of repose, h is the height of the pile, and r is the radius of the base of the pile. The angle of repose is usually expressed in degrees. A lower angle of repose indicates better flowability of the material.

2. Post compression parameters:

A. Thickness:

The thickness of individual tablets is measured by using Vernier caliper which gives the accurate measurement of thickness. It provides information on the variation of thickness between osmotic tablets. The unit for thickness measurement is mm. The limit for the thickness deviation of each tablet is ±5

B. Hardness:

The tablet hardness can be determined by Monsanto hardness tester. The tablet was held between a fixed and moving jaw. The scale was adjusted to zero loads was gradually increased until the tablet fractured. The value of the load at that point gives a measure of the hardness of the tablet. Hardness was expressed in Kg/cm2 .

C. Friability(F):

Tablet strength was tested by Friabilator. Tablets were initially weighed (WO) tablets were allowed for 100 revolutions, The tablets are taken out and were dusted and reweighed (W). The percentage of weight loss was calculated by rewriting the tablets. The % friability was then calculated by using the formula,

% Friability = F =(1- W0/W) *100

D. Weight variation test:

The weight of the tablet is measured to ensure that a tablet contains the proper amount of drug. The USP weight variation test was done by weighing 20 tablets individually calculating the average weight and comparing the individual weights to the average. The tablet meets the USP test if not more than 2 tablets are outside the percentage limits and if no tablets differ by more than 2 times the percentage limit. USP official limits of percentage deviation of the tablet are presented in the following table.

The average weight of tablets (mg)	Maximum percentage difference allowed
130 or less	±10
130-324	±7.5
More than 324	±5

E. Disintegration test:

The disintegration time is the time taken for a tablet to break up into small particles or fragments when immersed in a liquid medium under standard conditions. It is an important test to ensure that the tablet disintegrates within a specific time to release the drug for absorption. The disintegration test is performed using disintegration

International Journal of Pharmaceutical Research and Applications
Volume 8, Issue 3 May-June 2023, pp: 410-420 www.ijprajournal.com ISSN: 2249-7781

test apparatus, which typically consists of a basket rack assembly, a 1-liter beaker, and a standard motor.

During the test, tablets are placed in each tube of the basket rack assembly, which is then positioned in a beaker of the dissolution medium, such as water or simulated gastric fluid or simulated intestinal fluid, maintained at 37°C ± 2°C. The distance between the bottom of the tube and the bottom of the beaker is 2.5 cm. The basket is moved up and down through a distance of 5 to 6 cm at a frequency of 28 to 32 cycles per minute.

A tablet is considered to have disintegrated when no particle remains on the screen of 2 mm opening in the apparatus. The USP disintegration test requires all the tablets to disintegrate and the particles to pass through the #10 mesh screen within the specified time, which varies depending on the type of tablet and the intended use. The limit for disintegration time is typically 15 to 30 minutes for immediate-release tablets.

F. in-vitro dissolution studies

In in-vitro dissolution studies, the drug release rate is calculated as the percentage of drug released from the tablet over a period of time. The dissolution rate is usually calculated using a suitable equation or software. The amount of drug released is estimated by measuring the absorbance of the sample using UV-Visible spectrophotometer, and a calibration curve is prepared using standard solutions of the drug. The dissolution study is usually performed for a specified period of time, and the dissolution profile is compared with the standard dissolution profile. The dissolution profile is used to determine the drug release kinetics and the mechanism of drug release. The USP has specified dissolution methods for different dosage forms, and the dissolution apparatus used should be of a suitable type as per the USP guidelines.

MARKETED PRODUCT

Elementary Osmotic Pump

Brand Name	API
Efidac	Chlorpheniramine
Acutrim	Phenylpropanolamine
Sudafed 24	Pseudoephedrine
Sudafed 24	Albuterol
Minipress XL	Prazosin

Push-Pull Osmotic Systems

Ditropan XL	Oxybutynin chloride
Procardia XL	Nifedipine
Glucotrol	Glucotrol G
Covera HS	Verapamil HC
DynaCirc CR	DynaCirc CR
Invega	Paliperidone

Implantable Osmotic Systems

Viadur	Leuprolide acetate
Chronogesic	Sufentanil

II. CONCLUSION

In the osmotic delivery system, the osmotic pressure gradient is responsible for the controlled release of drugs. By controlling the influx of water into the system, the pressure inside the dosage form increases, which in turn pushes the drug out of the system at a controlled rate. One of the major advantages of this drug delivery system is the ability to precisely control the release rate of the drug, including zero-order or other patterned release over a prolonged period of time. Although it can be more expensive than other drug delivery systems, the osmotic drug delivery system has gained widespread acceptance in the pharmaceutical industry due to its reliable and consistent drug release profile.

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