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Review Article

Implantable Drug Delivery System

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ABSTRACT

In this paper, we present a shape-programmable magnetically actuated soft capsule robot for semiim plan table drug delivery applications. The shape of the proposed soft capsule is changed by an external magnetic field. To change the robot shape by an external permanent magnet, the relevant soft robot design features and required conditions are investigated using simulations and experiments. If the magnetic field is increased above a critical value, the capsule collapses to a sphere-like stable shape, which keeps the capsule inside the stomach all the time, and it cannot move to the duodenum by gastric peristalsis. We conducted experiments inside a synthetic stomach-like membrane to investigate how much tissue stress is induced by the soft capsule under emulated gastric peristalsis to show that the capsule induces no pain in the stomach and can sustain its spherical shape against external forces. Such a soft capsule can be used to release drugs, which can be contained on its body parts or inside a reservoir, while staying in the stomach. After depletion of the drug, a controlled rolling motion using the external magnetic field is proposed to recover the initial cylindrical shape. Then, the capsule can move into the duodenum by peristalsis and is discharged through the anus.

INTRODUCTION

Despite of progression and inventions in new administration of medicines, regulation of constant livery tube remedial indicator of medicines is still a big concern. The implicit detriment of using periodic oral or IV medicine administration comprises of elevated attention of drug(peaks) which contribute to adverse goods or shy attention of drug(troughs) which can lead to failure of remedy. The old way to overcome the issue of the variable attention of drug includes constant intravenous infusion rate dependent on drug pharmacokinetic profile. In order to minimise these unwanted issues, there's a need of ultramodern approach in achieving optimised rate of medicine discharge.[1]

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Implantable medicine delivery systems have implicit superiority in indigenous administration with better pharmacologic issues at minimal boluses. Due to which, they lower possible venom thereby perfecting liability for drug adherence. This kind of administration enables accessible delivering of specifics that are naturally inharmonious to be taken by oral way, escapes presystemic elimination as well as enzymatic destruction in tummy, therefore, remarkably enhancing bioavailability.[2]

Implantable bias have capability to minimise the need of frequent medicine input as well as authorize drug needs with approachable way. At present, these bias are generally employed in numerous remedial areas similar as contraception, chemotherapy, dentistry etc. The expanding product and request bareness of implants are apparent of immense growth in this sector(figure 1).[3]

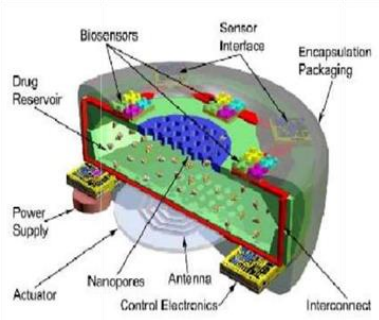


Fig 1: Illustration of an implantable drug device[4]

Implantables are generally named for their property of extended use with constant release of cure which will ultimately promote the case compliance.

Classification Of Implantable Polymeric Drug Delivery System:-

Passive Polymeric Implant: -

They're simple, singular and invariant bias, substantially contains simple medicine loaded in biocompatible matrix. They do not have any mobile part or fashion and depend on unresistant prolixity for release of medicine cargo. Passive bias can be subcategorised asnon-biodegradable and biodegradable.[5]

Non -Biodegradable Polemeric implant system-

The most common marketable forms are matrix-controlled or polymeric system and membrane enclosed force. Polymers like polyurethanes, polyacrylates, silicones or heteropolymers like polyethylene vinyl acetate(PEVA) are extensively used. In the matrix- controlled organisation, a cure is slightly distributed across the base. Gradational dissipation of bedded cure gives sustained release from delivery system. The dynamics of expatriation and release rate of cure is inconstant and relies on quantum of substance in the base. A force type system contains compact medicine defended bynon-biodegradable pervious subcaste whose periphery as well as penetrability rates impact release kinetics.[6,7] These bias are durable during their lifetime but need to be replaced after the medicine cargo is exhausted to avoid any negative impacts like infection, towel detriment and ornamental defects. These types of systems are extensively employed in contraception. Norplant is one of the foremost, extensively advanced force implant.[8]

Biodegradable polymeric implant system-

These systems offer advantages over nonbio-degradable bones and hence are more popular. Polymeric substances similar as polycaprolactone(PCL), polylactic acid(PLA), or polylactic- coglycolic acid(PLGA) are generally used for expression. The most desirable property

is that it uses inert polymers that resolve into small pieces and farther immersion and elimination takes place inside body therefore do n't bear any gash to prize out the device thereby perfecting patient acceptance and compliance. But these systems bear the degeneration of base of polymer for release of cure which is dependent on colorful factors like any change in body pH or temperature and thus extremely variable in individualities.(Table 1) 7 9, Their expression is likewise intricate than that of nonbiodegradable bones multitudinous factors are taken in view for their expression. Decomposition profile of polymeric base inside the body should be stable for keeping nonstop medicine discharge. To gain more invariant and constant medicine release, a flattened arbor- suchlike design without edge corrosion offers zeroorder profile is preferred. Two types ofbio-degradable bias are present. They are force system and monolithic types(figure 2). Reservoir system is analogous in construction and medium of medicine release as described innon-biodegradable systems. still, these bio disintegrated systems contain external membranous subcaste of polymer which disintegrates at moderate pace than that of dissipation across membrane. As a result, membrane stays innocent releasing behind the cure entirely. This complete membrane gets deteriorated inside the body which is eventually excreted out. The other kind is monolithic where cure is circulated in a polymeric substance and shows gradational corrosion with a steady release inside the body

Active or dynamic polymeric implants-

This kind of Implantables use definite propulsion in regulating discharge of drug across the aid. therefore it offer advanced standard in medicine discharging. They use some feathers of energy dependent styles for positive impulse to regulate discharge. The power origin can range different from bibulous pressure grade to electromechanical forces.

Table 1: Examples of biodegradable polymers

Class	Examples
Polypeptides	Soy protein, Zein, Silk
Polysaccharides	Cellulose, Starch, Xanthan
Polyesters	Polylactic acid, Polyvinyloxyalkonates
Lipids	Surfactants, Waxes
Polyphenols	Lignin, Tannin
Speciality polymers	Natural rubber, Nylon (from castor oil), Shellac

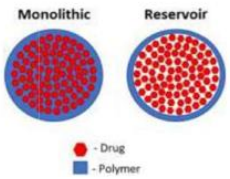


Fig 2: Types of dynamic or active implantable

Mechanism of drug discharge implant from implant device :-

There are primarily four ways of drug discharge through the implant bias – polymer decomposition, optimised expansion, osmosis and simple prolixity. Implants amusement by optimised expansion, water immersion in device controls medicine discharge which is generally shy over normal dissipation and therefore contributes to a steady proportion of release. The decomposition of expanded matrix allows prolixity of medicine substantially and perfecting the disintegrating capacity of the matrix significantly enhances the effectiveness of the implant. Osmosis intermediated release and free prolixity ways of medicine release are applicable for delivering medicines linearly where the volume of delivered medicine relies proportionally to square root of discharge duration. Osmosis is simple passage of waterless

motes from an area of low attention to a lesser attention via a semipermeable membrane which creates a pressure grade. prolixity workshop by process in which solute moves voluntary in all areas to souse chemical composition. The mobile substances are called diffusants and a membrane through which diffusants peregrination is known as diffusional hedge. The attention grade is the impulsion for the release of cure from system. However the discharge profile of medicines depends upon contents of delivery system which in turn relies on factors like imbibition, bibulous pressure, and unresistant prolixity, and motes stability, prolixity measure in polymer, medicine content, and decomposition rate of polymer in vivo(figure 4)[10]

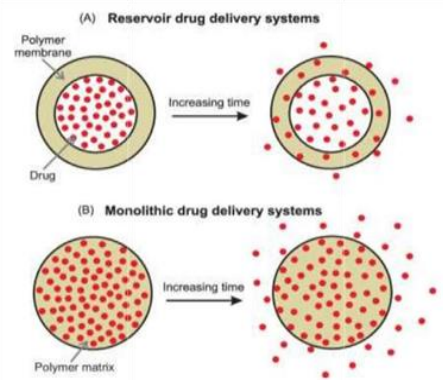


Fig 4: Demonstration of drug release from polymer matrices (16)

Method of implant manufacture:

1.Hot melt extrusion:

To create a solution mixture, the medication is prepared to dissolve in the proper solvent. After that, the polymer is gradually added and left to soak for 15 to 20 minutes. The product that is swollen is mixed well until it takes the consistency of dough, then it is transferred into an ejection cylinder to create an elongated rod-like structure using a showerhead. After being allowed to cure overnight at room temperature, the product is cut to the necessary size. The final product is obtained by dehydrating it at 41 degrees Celsius.

Effective output is possible when extrusion is done concurrently (figure 5A). Thermoplastic polymeric materials, such as polyamide aliphatic polyesters like PLA, PGA, and PLGA, are necessary. Non solvents are necessary for it. However, this may result in degeneration of heat sensitive medications. Zoladex® and Implanon® like devices are produced by this technique.

2.Compaction:

The medication and polymer are lyophilised to create a cake after being dispersed to create a suspension. Carver exposes it to more compaction in order to create an implant. hydraulic device having a metric tonne of force. It has the benefit of not requiring heating or solvents, making it perfect for creating implants with thermolabile materials, particularly proteinaceous content. Because of their rapid release profile, these implantables must be optimised by stacking. Furthermore, the uneven look of the manufactured implants and their many cavities may be further factors in their erratic discharge.[11 10]

Moulding:-

After being heated and put into a mould, the polymeric material is allowed to solidify. The relative molecular mass of the polymers decreases. because of the intense heat that was used. This technique amplifies molecular mass and dispersability, which can be reduced in a variety of ways. Therefore, in contrast to factory-made mistreatment injection moulding, these implantable dissolved earlier (figure 5B). 12

3D Printing :-

It is a low-cost, reliable, and adaptable process that may prove helpful in the future, particularly for the rapid production of standard units for research. But it's not utilised in large quantities, but when the FDA authorised one such substance in 2015, its applicability advanced. This method is mostly utilised to create implants and prostheses for orthopaedics and dentistry.[13]

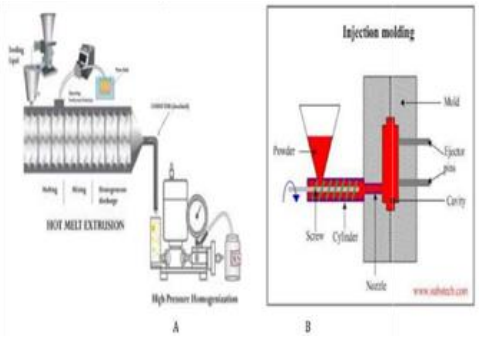


Fig.5 Method of Manufacture of implant-(A)Hot melt extrusion[14] (B) moulding method [15]

Implantable Controlled releases microchip :design and component-

In order to properly manage drug distribution, it might be challenging to exactly modify the geometry of drug-loaded system susing standard drug delivery techniques. Microfabrication technology for MEMS, which uses the same processing techniques used to create microprocessors for computer microchips has been used for drug delivery systems[16] as one of the most advanced ways to get around these restrictions. Device circuitry can be constructed and programmed to open seals on individual reservoirs and release medicament, and reservoirs on silicon chips can be filled with medication and sealed to safeguard and confine it thanks to MEMS technology.

Polymers used for implantable polymeric drug delivery devices:-

Biodegradable and non-biodegradable polymers are the two types of polymers used to make implantable drug delivery systems . The requirement for surgical removal or the buildup of polymer in the body following use are two significant drawbacks of non-biodegradable implants [17]. A research by Odom et al. [18] found that the surgical removal of non-biodegradable implants is frequently more traumatic than their insertion [19]. The study looked into the removal of the Nexplanon® non-biodegradable contraceptive implant and came to the conclusion that a multidisciplinary care team and a peripheral nerve surgeon's experience might help remove these implants successfull[18]. As an alternative, biodegradable polymers have the important benefit of not requiring surgical removal after use. They are made to break down organically into goods that. The application of polymers in medication delivery and tissue engineering has been extensively studied. Polymers, both synthetic and natural, have been studied [20]. In contrast to natural polymers, synthetic polymers are often biologically inert, have predictable chemical and physical characteristics, and do not exhibit batch-to-batch variability[21]. When creating a medication delivery system, the material's biodegradability and biocompatibility are crucial[22]. All materials must be completely biocompatible, and any modifications to the properties of the polymer that arise during degradation must be thoroughly examined and described. Any biodegradable polymer should ideally be highly replicable, quickly metabolized and eliminated by physiological processes, degradable to non-toxic compounds, and immune to inflammation in vivo.[22] There isn't a single perfect polymer;

instead, the mechanism and intended rate of release will determine which polymer is best. A combination of polymers may be needed to get the desired properties.

Biodegradable Polymer:-

Thermoplastic Aliphatic Polyesters:-

Poly (lactic acid) (PLA), poly(glycolic acid) (PGA), and poly(lactic-co-glycolic acid) (PLGA) (Figure 3) are examples of thermoplastic aliphatic poly(esters) that have been extensively studied because of their advantageous properties, which include mechanical strength, biodegradability, and biocompatibility[23]. These polymers have been effectively employed in solid and microparticle parenteral implants as well as drug delivery systems based on nanoparticles . These polymers can degrade over a period of one month to more than six months [24]. Figure 4 depicts the PLA, PGA, and PLGA degradation mechanisms. Hydrophilicity, glass transition temperature, molecular weight, and environmental parameters including pH and temperature all have an impact on degradation rate [24].

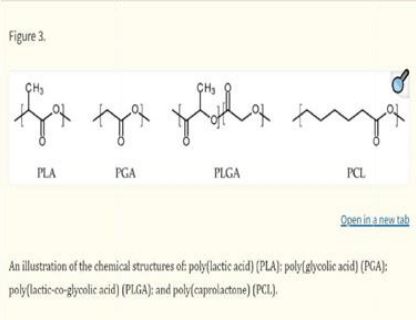


Figure 3.

An illustration of the chemical structures of: poly(lactic acid) (PLA): poly(glycolic acid) (PGA): poly(lactic-co-glycolic acid) (PLGA): and poly(caprolactone) (PCL).

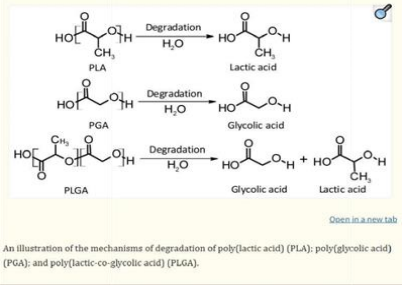


Figure 4.

An illustration of the mechanisms of degradation of poly(lactic acid) (PLA): poly(glycolic acid) (PGA); and poly(lactic-co-glycolic acid) (PLGA).

Poly (lactic acid):-

The polymerization of lactic acid derived from natural feedstock (such as corn starch, rice, or potatoes, among others) yields poly(lactic acid) (PLA), a biodegradable and bioresorbable polymer with promising qualities for medical applications [25]. The mechanical properties of PLA are comparable to those of other synthetic polymers, including polypropylene, although PLA is more abundant, less expensive, and biodegradable . PLA is more likely to biodegrade than other biomedical polymers because it is semipermeable to both oxygen and water . Being a generally recognized as safe (GRAS) material, PLA has been approved by the US Food and Drug Administration (FDA) for use in direct contact with biological fluids . Because PLA is so thermally processable, it can be processed in a wide range of ways [25]. PLA is a white powder at ambient temperature with melting and glass transition temperatures of approximately 175 and 55 °C, respectively. The characteristics of PLA with a high molecular weight are comparable to those of polystyrene. Both kinds of monomers can be used to create PLA since lactic acid has two stereoisomers (d and l) . Because of its regular chain structure, PLA made from d-lactic acid, or PDLA, is a crystalline substance. The PLA produced using l-lactic acid, or PLLA, will, nevertheless, have a hemicrystalline structure . Furthermore, an amorphous polymer can be

produced by preparing PLA with a combination of both (PDLLA) . A broad range of organic solvents, including acetonitrile, tetrahydrofuran, dioxane, benzene, and chloroform, can dissolve all of these polymers[26].

Poly (gycolic acid):

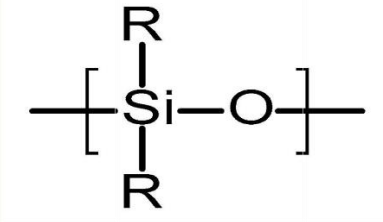
A polyester known as poly(glycolic acid) (PGA) is created by polymerizing glycolic acid units. In terms of biomedical applications, it was among the earliest biodegradable polymers. Only one extremely crystalline version of the polymer PGA is known to exist . It has outstanding mechanical qualities (better than PLA) and a melting point above 200 °C . Dexon® and other biodegradable sutures derived from PGA have been effectively employed. PGA is insoluble in a wide range of common solvents and shows a rapid degradation profile. Therefore, this polymer hasn't been employed by itself to deliver drugs. Glycine is produced when PGA is broken down in bulk by the scission of its ester backbone and is eliminated by the citric acid cycle or urine.[20]

Non -Biodegrable Polymer

Poly (siloxanes) :-

Organosilicon polymeric compounds made of silicon and oxygen atoms are known as poly(siloxanes) or silicones . The chemical structure of this kind of polymer is depicted in Figure 5. Methyl, vinyl, or phenyl groups are examples of lateral groups . These groups will affect the polymer's characteristics. Because of their special blend of elastomeric, chemically inert, thermal, and biocompatible qualities, poly(siloxanes) have found widespread application in medicine. At room temperature, silicones that are frequently employed in medical equipment are vulcanized. They are made with a catalyst (a chemical based on platinum) and a two-component poly(dimethylsiloxanes) (PDMS) . An addition hydrosilation process creates the final substance [20].

Figure 5.



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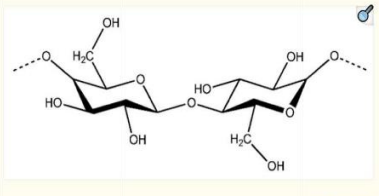
An illustration of the chemical structure of poly(siloxane).

Cellulose: -

The most prevalent organic substance in the world is cellulose, which is mostly made by plants. The structure of cellulose, a naturally occurring linear polymer (polysaccharide), is made up of lengthy chains of repeating β-d-glucopyranose units that are covalently joined by acetal functionalities between the equatorial −OH group of C4 (β-1,4-glycosidic bonds) and the C1 carbon atom [20].

Figure 8.



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An illustration of the chemical structure of cellulose [80].

Numerous uses have led to extensive research on cellulose and its various derivatives, such as bacterial cellulose (BC), cellulose ethers and esters, and micro/nanosized cellulose products (. Modulevsky et al., for example, developed implantable cellulose scaffolds using the native hypanthium tissue of apples . This strategy complements the application of BC, which has been effectively used in the creation of implantable materials. BC is a viable choice for a wide range of medical applications because of its characteristics and nanostructure. Because BC fibers have a high degree of crystallinity and an endotoxin level that falls within the FDA-recommended range for implants, they may be utilized safely in intravenous applications. It has been demonstrated that BC has better qualities than plant-derived.[27]

Current Therapeutic Application:-

Implantable drug delivery devices have the potential to be used for a wide variety of clinical applications in areas including, but not limited to: women's health, oncology, ocular disease, pain management, infectious disease and central nervous system disorders [17]. Examples of implantable drug delivery devices for each of these areas are summarised in Tables 1–4. Women's health is one area where implantable drug delivery devices have had a large impact, particularly in their use for contraception. In 1990, Norplant became the first implantable contraceptive device to be approved. Implantable long acting contraceptives have been shown to be the among the most effective method of birth control, with women who use these methods experiencing a pregnancy rate of less than 1% year. Examples of implantable medication delivery systems for women's health are displayed in Table 1. The most popular method of administering chemotherapeutic drugs is systemic distribution. Nevertheless, it frequently entails administering the drugs at the highest dose that can be tolerated, which may result in serious adverse effects as cardiomyopathy and neutropenia[28]. installation of a medication delivery device near the site of action might provide less systemic exposure, which would lessen the harm done to healthy tissue. Table 2 lists a few instances of implantable medication delivery systems used to treat cancer.

Table 1:- Example of Implantable drug delivery devices use in the area of woman's health.

Product Name	Implant Type	Material	Drug Delivered	Indication
Norplant®	Sub-cutaneous	Silicone	Levonorgestrel	Contraception
Jadelle®				
Estring®	Intra-vaginal	Silicone	Estradiol	Menopausal symptoms
Nuvaring®	Intra-vaginal	PEVA	Etonogestrel, Ethinyl estradiol	Contraception
Implanon®	Sub-cutaneous	PEVA	Etonogestrel	Contraception
Nexplanon®				

Table 2:- Example of implantable drug delivery device use for anticancer therapy. ND= Not Disclosed.

Product Name	Implant Type	Material	Drug Delivered	Indication
Zoladex®	Sub-cutaneous	PLGA	Goserelin	Prostate cancer
Prostap®SR	Sub-cutaneous	PLGA	Leuprolide	Prostate cancer
Gliadel Wafers®	Intra-tumoral	Silicone	Carmustine (BCNU)	Primary malignant glioma
Oncogel®	Intra-tumoral	PLGA-PEG-PLGA	Paclitaxel	Oesophageal cancer
Vantas®	Sub-cutaneous	Methacrylate based hydrogel	Histrelin	Prostate Cancer
GemRIS®	Intra-vesical	ND	Gemcitabine	Non-muscle invasive Bladder Cancer

Because of the distinct morphological and physiological obstacles that the ocular environment provides, drug transport to the posterior portion of the eye is challenging. For ocular disorders to be successfully treated, the dosage of medication or therapeutic agent must be administered to the site of action and kept for as long as the treatment is necessary. Due to lacrimation, tear dilution, and tear turnover, poor drug retention and poor drug penetration in the eye make this especially difficult [29]. Poor patient compliance and challenging device use related to ocular disorders further exacerbate these problems [30]. By lowering the number of therapy applications needed, implantable drug delivery devices help to alleviate some of these delivery issues, but they also have drawbacks.

Table 3:- Example of implantable drug delivery device use to treat ocular disease.

Product Name	Implant Type	Material	Drug Delivered	Indication
Ocusert®	Intra-ocular	PEVA	Pilocarpine, Alginic acid	Open angle glaucoma
Retisert®	Intra-ocular	Microcrystalline cellulose, PVA, Magnesium stearate	Fluocinolone	Non-infectious uveitis
Vitrasert®	Intra-ocular	PVA, PEVA	Ganciclovir	CMV retinitis in AIDS patients

It looks promising to employ implanted drug delivery systems to treat pain. In addition to being exceptionally challenging to treat, chronic pain is linked to a significant risk of addiction or overdose death[31]. Devices for implanted drug delivery may prove useful in the treatment of infectious disorders. and specifically tuberculosis. The duration of TB treatment is lengthy, and the medications utilized have adverse effects. Treatment failure and the emergence of resistance are frequently caused by these variables, which also lead to poor patient compliance with the prescribed course of action. To guarantee patient adherence and treatment completion in this situation, an implantable medication delivery system would be perfect. Antipsychotic therapy is frequently not followed by patients, which increases the risk of relapse and hospitalization.[32]

Table 4. Example of implantable drug delivery device for pain management infection disease and central nervous system disorder. ND: Not disclose.

Therapeutic Indication	Product Name	Implant Type	Material	Drug Delivered	Indication
Pain	ND (Axxia Pharmaceuticals)	Sub-cutaneous	PU, PEG/PPG/ PTMEG	Hydromorphine	Chronic neuropathic pain
	LiRIS®	Intra-vesical	Silicone	Lidocaine	Interstitial cystitis/bladder pain syndrome
	Probuphine®	Sub-cutaneous	PEVA	Buprenorphine	Opioid abuse
Infectious Diseases	ND	ND	PLGA	Isoniazid	TB
	ND	ND	PLGA	Isoniazid, Pyrazinamide	TB
Central Nervous System disorders	Med-Launch	Sub-cutaneous	PLGA	Risperidone	Schizophrenia
	ND	Sub-cutaneous	PU	Risperidone	Schizophrenia
	Risperdal consta®	Intra-muscular	PLGA	Risperidone	Schizophrenia

ADVANTAGES:

Targeted drug delivery: -

The capacity of implantable drug delivery devices to deliver drugs straight to the body's designated location of action is one of their main benefits. Implants guarantee localized distribution, optimizing the drug's concentration at the intended site, in contrast to conventional oral drugs, which are administered systemically [33]. When treating disorders like cancer, inflammatory diseases, and chronic pain, where accurate drug distribution is crucial for therapeutic efficacy, this focused approach is especially helpful.

Reduced side effect:-

Unlike oral or intravenous administration, implanted drug delivery systems reduce systemic

exposure and possible side effects by delivering drugs directly to the site of action. This focused strategy improves patient safety and acceptability by lowering the possibility of negative reactions in non-target tissues and organs [33].

Improved patient adherence:-

Patient adherence to treatment is improved by implantable drug delivery systems, which provide a practical substitute for traditional medicine. In contrast to oral drugs that need to be taken often and could be overlooked or omitted, implants offer a permanent fix with little assistance from the patient[22]. For people who have complicated drug schedules or who struggle to remember to take their medications on a regular basis, this can be especially helpful.

Disadvantages:

Surgical implantation: -

One of the primary drawbacks of implantable drug delivery systems is the need for surgical implantation, which can be invasive and carry associated risks such as infection, bleeding, and tissue damage. The surgical procedure requires skilled healthcare professionals and specialized equipment, adding to the overall cost and complexity of treatment[19]. Additionally, some patients may be reluctant to undergo surgery or may not be suitable candidates due to underlying medical conditions.

Risk of device malfunction: -

Implanted drug delivery systems are intricate medical devices that require well-designed and functional parts. Device failure or malfunction is a possibility, which could jeopardize medication delivery and call for replacement or further procedures [18]. Over time, mechanical problems like blocked drug reservoirs or broken valves can arise, resulting in less than ideal treatment results and possible consequences.

Limited compatibility with certain drugs:-

Because of things like drug solubility, stability, and compatibility with the materials of the device, not all medications can be administered by implantable drug delivery systems. Over time, the usefulness of certain medications may be limited as they may deteriorate or lose their strength while being stored inside the implant[20]. Furthermore, some medications may cause tissue irritation or inflammation with extended use, which calls for careful formulation and drug selection.

CONCLUSION: -

Implantable medication delivery devices made of polymers are seeing growth in the market. Given its benefits over more traditional drug administration techniques, such oral pills, this delivery method is probably going to keep expanding, and the number of implanted The market for medicine delivery devices will grow. However, there are a number of drawbacks to implantable medication delivery systems, one of which is that it is an invasive delivery method. These devices have more benefits than drawbacks, including the capacity to improve patient compliance, stabilize medications inside, and be removed in the event of an unpleasant reaction. In this article, the therapeutic uses of implanted drug delivery systems are discussed. But the application of has the potential to extend much beyond the aforementioned parameters for implantable medication delivery systems. Human immunodeficiency disease (HIV) therapy or prevention is one such situation where these gadgets could have a significant influence. 3D printing presents an intriguing opportunity. is a fascinating new manufacturing technique that offers a special chance to create intricate designs or customized implanted gadgets. However, this manufacturing process has greater scale-up and regulatory issues than more conventional approaches to implantable device manufacturing, including hotmelt extrusion or compression molding. The likelihood of 3D printing being used in pharmaceutical manufacture has increased

significantly after the FDA approved the first 3D printed pill in 2015.

REFERENCES

1. Danckwerts M, Fassihi A. Implantable controlled release drug delivery systems: A review. Drug Dev Ind Pharm. 1991;17(11):1465-1502. doi:10.3109/03639049109026629
2. Stewart SA, Domínguez-Robles J, Donnelly RF, Larrañeta E. Implantable polymeric drug delivery devices: Classification, manufacture, materials, and clinical applications. Polymers (Basel). 2018;10(12). doi:10.3390/polym10121379
3. Saettone MF, Salminen L. Ocular inserts for topical delivery. Adv Drug Deliv Rev. 1995;16(1):95-106. doi:10.1016/0169-409X(95)00014-X
4. Rajgor N, Patel M, Bhaskar VH. Implantable drug delivery systems: An overview. Syst Rev Pharm. 2011;2(2):91-95. doi:10.4103/0975-8453.86297
5. Claes L, Ignatius A. Entwicklung neuer biodegradabler Implantate. Chirurg. 2002;73(10):990-996. doi:10.1007/s00104-002-0543-0
6. Tian W, Mahmoudi M, Lhermusier T, et al. The influence of advancing age on implantation of drugeluting stents. Catheter Cardiovasc Interv. 2016;88(4):516-521. doi:10.1002/ccd.26333
7. Bourges JL, Bloquel C, Thomas A, et al. Intraocular implants for extended drug delivery: Therapeutic applications. Adv Drug Deliv Rev. 2006;58(11):1182-1202. doi:10.1016/j.addr.2006.07.026
8. Kumar A, Pillai J. Implantable Drug Delivery Systems: An Overview. Elsevier Inc.; 2018. doi:10.1016/B978-0-12-813665-2.00013-2
9. Wang X, Chen T, Yang Z, Wang W. Study on structural optimum design of implantable drug delivery micro-system. Simul Model Pract Theory. 2007;15(1):47-56. doi:10.1016/j.simpat.2006.09.017
10. Amreen S, Shahidulla SM, Sultana A, Fatima N. Implantable Drug Delivery System: An Innovative Approach. J Drug Deliv Ther. 2023;13(5):98-105. doi:10.22270/jddt.v13i5.6069
11. Breitenbach J. Melt extrusion: from process to drug delivery technology. Eur J Pharm Biopharm. 2002;54(2):107-117. doi:10.1016/S0939-6411(02)00061-9
12. Jivraj M, Martini LG, Thomson CM. An overview of the different excipients useful for the direct compression of tablets. Pharm Sci Technol Today. 2000;3(2):58-63. doi:10.1016/S14615347(99)00237-0
13. Rothen-Weinhold A, Besseghir K, Vuaridel E, et al. Injection-molding versus extrusion as manufacturing technique for the preparation of biodegradable implants. Eur J Pharm Biopharm. 1999;48(2):113-121. doi:10.1016/S0939-6411(99)00034-X
14. Norman J, Madurawe RD, Moore CMV, Khan MA, Khairuzzaman A. A new chapter in pharmaceutical manufacturing: 3D-printed drug products. Adv Drug Deliv Rev. 2017;108:39-50. doi:10.1016/j.addr.2016.03.001
15. Patil H, Feng X, Ye X, Majumdar S, Repka MA. Continuous Production of Fenofibrate Solid Lipid Nanoparticles by Hot-Melt Extrusion Technology: a Systematic Study Based on a Quality by Design Approach. AAPS J. 2015;17(1):194-205. doi:10.1208/s12248-014-9674-8
16. Polla DL, Erdman AG, Robbins WP, et al. Icrodevices in. Published online 2000.
17. Dash AK, Cudworth GC. Therapeutic applications of implantable drug delivery systems. J Pharmacol Toxicol Methods. 1998;40(1):1-12. doi:10.1016/S1056-8719(98)00027-6

18. Odom EB, Eisenberg DL, Fox IK. Difficult removal of subdermal contraceptive implants: a multidisciplinary approach involving a peripheral nerve expert. Contraception. 2017;96(2):89-95. doi:10.1016/j.contraception.2017.05.001
19. Sun H, Mei L, Song C, Cui X, Wang P. The in vivo degradation, absorption and excretion of PCL-based implant. Biomaterials. 2006;27(9):1735-1740. doi:10.1016/j.biomaterials.2005.09.019
20. Nair LS, Laurencin CT. Biodegradable polymers as biomaterials. Prog Polym Sci. 2007;32(8-9):762798. doi:10.1016/j.progpolymsci.2007.05.017
21. Ginjupalli K, Shavi GV, Averineni RK, Bhat M, Udupa N, Nagaraja Upadhya P. Poly(α-hydroxy acid) based polymers: A review on material and degradation aspects. Polym Degrad Stab. 2017;144:520535. doi:10.1016/j.polymdegradstab.2017.08.024
22. Ulery BD, Nair LS, Laurencin CT. Biomedical applications of biodegradable polymers. J Polym Sci Part B Polym Phys. 2011;49(12):832-864. doi:10.1002/polb.22259
23. Anderson JM, Shive MS. Biodegradation and biocompatibility of PLA and PLGA microspheres. Adv Drug Deliv Rev. 2012;64(SUPPL.):72-82. doi:10.1016/j.addr.2012.09.004
24. Makadia HK, Siegel SJ. Poly Lactic-co-Glycolic Acid (PLGA) as biodegradable controlled drug delivery carrier. Polymers (Basel). 2011;3(3):1377-1397. doi:10.3390/polym3031377
25. da Silva D, Kaduri M, Poley M, et al. Biocompatibility, biodegradation and excretion of polylactic acid (PLA) in medical implants and theranostic systems. Chem Eng J. 2018;340:9-14. doi:10.1016/j.cej.2018.01.010
26. Xiao L, Wang B, Yang G, Gauthier M. Poly (Lactic Acid) -Based Biomaterials : Synthesis , Modification and Applications.; 2012.
27. Klemm D, Heublein B, Fink HP, Bohn A. Cellulose: Fascinating biopolymer and sustainable raw material. Angew Chemie - Int Ed. 2005;44(22):3358-3393. doi:10.1002/anie.200460587
28. Rahimi A, Mashak A. Review on rubbers in medicine: Natural, silicone and polyurethane rubbers. Plast Rubber Compos. 2013;42(6):223-230. doi:10.1179/1743289811Y.0000000063
29. Manickavasagam D, Oyewumi MO. Critical Assessment of Implantable Drug Delivery Devices in Glaucoma Management. J Drug Deliv. 2013;2013:1-12. doi:10.1155/2013/895013
30. Gooch N, Molokhia SA, Condie R, et al. Ocular drug delivery for glaucoma management. Pharmaceutics. 2012;4(1):197-211. doi:10.3390/pharmaceutics4010197
31. Bobo W V, Shelton RC. Risperidone long-acting for maintenance treatment in patients with bipolar disorder. Expert Rev Neurother. Published online 2010:1637-1658.
32. Siegel SJ, Winey KI, Gur RE, et al. Surgically implantable long-term antipsychotic delivery systems for the treatment of schizophrenia. Neuropsychopharmacology. 2002;26(6):817-823. doi:10.1016/S0893-133X(01)00426-2
33. Fu Y, Kao WJ. Drug release kinetics and transport mechanisms of non-degradable and degradable polymeric delivery systems. Expert Opin Drug Deliv. 2010;7(4):429-444. doi:10.1517/17425241003602259.

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