Robotic Pills: The Future of Personalized Medicine

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***Abstract*—Robotic technologies are being developed in the pharmaceutical business to address global healthcare system concerns. The robotic pill protects itself from degradative enzymes by avoiding first-pass metabolism. When consumed frequently, robotic pills improve systemic pharmaceutical bioavailability, offer a therapeutically optimal amount, and have no negative side effects. Using these formulations reduces the need for needle injections. As a result, patients become more receptive and needle use becomes less challenging. Proteins and peptides administered orally encounter a number of serious challenges, including toxicity, expense, and quality. Several issues associated with non-adherence, including discomfort, injection pain, and disruption of daily activities, may be resolved by oral dose formulations** (Singh A W. S., A Robotic Pill: An Innovative Technology in Drug Delivery.)**. The gastrointestinal tract's degradative environment and low absorption limit oral protein medication distribution, necessitating parenteral treatment. The first steric and dynamic barrier to absorption is luminal mucus. We describe the creation of the Robo Cap, an oral ingestible, robotic drug delivery capsule that improves luminal mixing, topically deposits the drug payload in the small intestine to improve drug absorption, and locally clears the mucus layer in order to get beyond this obstacle** (Srinivasan SS, 2022)**.**

***Index Terms*—Robotic pill, .**

I. INTRODUCTION

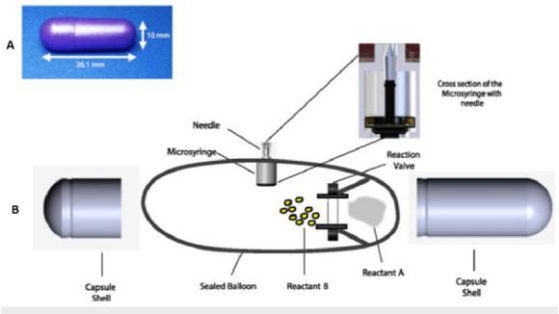
By combining pharmaceutical technology with drug delivery expertise, robotic pills can be created effectively utilised to improve drug adherence and penetration through the GI tract's mucous membrane resulting in medication delivery at the intended location.

A robotic oral ingestion drug delivery device that enhances mixing, applies the drug payload topically, and removes mucus locally to boost medication absorption. The robotic pill shields against degradative enzymes by bypassing first-pass metabolism and speeds up the rate at which medication is administered throughout the GI mucosal membrane. Designing oral doses could address several issues associated with non-adherence, including discomfort, injection pain, and interruption of daily activities. The gastrointestinal (GI) tract's deteriorating environment and low absorption limit oral medication delivery, despite the fact that it is the most widely used, cost-effective, and practical method of drug administration for macromolecules like proteins and nucleic acids. In order to achieve therapeutic bioavailability, medications must dissolve in GI fluid, cross the thick mucus barrier, penetrate the stomach's harsh acidic environment, stay stable among the degradative enzymes and active intestinal flora, and stay out of the way of efflux pumps. There is a small chamber inside the robotic pill that holds the medicine payload. There are protuberances and ridges on the outside, and a gelatin covering it that dissolves at a specific pH. After the tablet is ingested, its covering wears off as it passes through the stomach. When the pH of the small intestine changes, a motor inside the capsule begins to spin the pill. A normal shot should cause more pain than this needle puncture. Some feelings, such as the intense pain associated with a stomach ulcer, can be felt in the stomach or the unpleasant sensation of being bloated but those feelings are more closely related to stretch receptors. The sensors in the stomach do not detect sharp pains, like those caused by an injection. Patients may not need daily needles or visit the hospital to acquire their medications thanks to Robo Cap. The current challenge of administering numerous cutting-edge and novel treatments orally is intended to be addressed by the novel idea known as Robo Cap (Goldberg M, 2003).

II. STRUCTURE AND FUNCTIONS

An HPMC capsule the size of a 000 contains the mechanical device known as the RP (Fig. 1a), which is swallowable (ACG Worldwide). The primary components of the RP, which are contained inside a

specifically designed polyethylene balloon measuring 752 mm in length and 21–25 mm in diameter, are visible in an expanded picture in Figure 1b. The hollow, dissolvable polyethylene glycol needle that holds the medication payload is enclosed in a cylindrical, 14.5 by 8.5-millimeter (14.58.5 mm) polyethylene micro syringe that is attached to the balloon. The solid drug payload is contained within the balloon by this micro syringe. A dissolvable reaction valve that separates two reactants (potassium bicarbonate and citric acid) is made of polyethylene oxide, which dissolves readily in intestinal fluid. Equipped with a Caleva small coater (agitation 8-15 Hz, pump 1.3-15 rpm, and atomising pressure 10-20 psi), the capsule is coated with a pH-sensitive polymer suspension of Eudragit L30-D55 (MW 320,000 g/mol) and 0.1-0.5% Plasacryl-HTP20 (Evonik). The device's components have been categorised by the FDA as either food grade, food additives, active or inactive food ingredients, or GRAS (generally regarded as safe).



Inset shows the micro syringe containing the needle with the drug micro tablet which gets injected into the jejunal wall. The micro tablet and needle are aseptically manufactured in an isolator and hermetically sealed inside a drug chamber which is then inserted in the micro syringe (Singh A W. S., A Robotic Pill: An Innovative Technology in Drug Delivery.).

III. MATERIALS AND METHODS

A. RP description and operation:

The RP is a mechanical device that may be swallowed and is contained in a hydroxypropyl methylcellulose (HPMC) capsule that is the size of a thousand (ACG Worldwide). An enlarged view of Figure 1b reveals the main parts of the RP, which are contained within a specially made polyethylene balloon that is 75 ± 2 mm long and has a diameter of 21–25 mm. The medication payload is contained in solid form in a polyethylene micro syringe that is cylindrical and 14.5 x 8.5 mm. enclosed within a hollow, dissolvable, 5.1 ± 0.13 mm long polyethylene glycol needle. A dissolvable reaction valve composed of polyethylene oxide, which easily dissolves when exposed to intestinal fluid, keeps the two reactants—potassium bicarbonate and citric acid—separated inside the balloon. Using a Calva mini coater (agitation 8-15 Hz, pump 1.3-15 rpm, atomizing pressure 10-20 psi), the capsule is enteric-coated using a pH-sensitive polymer suspension of Eudragit L30-D55 (MW 320,000 g/mol) and 0.1-0.5% Plasacryl-HTP20 (Evonik).

B. Device safety and tolerability assessment:

Every subject responded favorably to the RP. No subject experienced any problems or difficulties ingesting the RP. None of the individuals experienced any significant side effects. Twenty-three participants reported a total of 29 adverse events of grading levels 1 and 2 (mild to moderate), all of which abruptly stopped without any help. The prolonged fasting period and/or known octreotide side effects were probably the cause of the majority of the adverse events that were noted, which included light headedness, diarrhea, headache, and nausea. There was no need for intervention because the abdominal discomfort that one participant in group B and two in group C reported went away on its own. Each case was further examined, and it was determined that the origin of the stomach pain was not related to the RP because it did not occur at the same time as the device deployment. Fluoroscopic imaging performed during the follow-up visits on days 3–7 verified that all individuals had excreted device remnants from the GI system without experiencing any side effects. Throughout the trial, every clinical laboratory test and physical examination was normal.

Pharmacokinetics and bioavailability of octreotide delivered via the RP

Octreotide's presence or absence in at least one blood sample taken from each participant in the three RP groups was used to evaluate if drug delivery was effective or failed, which was the basis for scoring the RP's reliability. Figure 4 displays the three RP variants' drug delivery success rates. With the three RP versions, the success rate increased gradually. The smallest size RP (group A) had the lowest rate (3 out of 12 successful deliveries, or 25%), followed by the intermediate size RP (10 out of 20 successful deliveries, or 50%) and group C (80%, or 16 out of 20 successful deliveries).

As mentioned in the reliability section above, three participants in group A and ten subjects in group B had complete PK curves. Since the dosage of the drug was the same for groups A and B, data were combined (N = 13) for PK analysis and octreotide bioavailability assessment. In Fig. 5b, the concentration–time profiles of octreotide given via IV injection and RP are displayed. When administered intravenously (11.1 ng/ml), the peak plasma concentration (C max) of octreotide was higher than when administered RP (2.4 ng/ml). As anticipated, IV required less time (5 min) to reach peak plasma concentration (T max) than RP (50 min). As anticipated, the IV plasma concentration (T max) was lower (5 min) than the RP plasma concentration (50 min). When compared to oral delivery, octreotide IV exposures were higher in patients; the mean AUC last/dose value was 1.7 times higher in the IV group than in the RP group (389 vs. 226 min ng/mL μg/kg). Weight-normalized AUC indicates that the mean bioavailability (% F) of octreotide administered through the RP was 65 ± 9%. Geometric coefficient of variation (CV%) for all PK parameters with the RP was comparable to that of the IV group (range 13 to 72%) and was moderate (range 21 to 92%).[{6}]

ROBOTIC PILLS AIMS TO REPLACE INSULIN SHOTS, INJECTED ANTIBIOTICS

To distribute solid biologic formulations, the scientists first showed that their self-orienting milli meter-scale applicator (SOMA) device could. Because they dissolve more slowly and have a longer shelf life than their liquid equivalents, these solid medications are ideal for uses like administering long-acting insulin. Insulin was compressed by the researchers into a pointed structure that serves as a needle and a medication as a model system. Insulin-loaded SOMA devices were inserted into swine stomachs using an endoscope. Through the capsule's vents, gastric fluid entered the gadget. The actuator made of sugar glass broke apart, releasing the spring. The insulin needle was injected into the stomach tissue, where it was dissolved. Without harming the stomach's outer muscle layer, the researchers found that the medication needle could pass through the mucus lining. When they injected the medication through the SOMA, they observed a drop in blood glucose and insulin plasma concentrations that were similar to what they observed when they inserted the insulin needle beneath the skin.

After loading the liquid injection device (called L-SOMA) with either insulin, epinephrine, an analogue of the peptide GLP-1, or the antibody adalimumab, the researchers endoscopically inserted the capsules into the stomachs of pigs (Dhalla AK, Dhalla AK, Al-Shamsie Z, Beraki S, Dasari A, Fung LC, Fusaro L, Garapaty A, Gutierrez B, Gratta D, Hashim M, Horlen K. A robotic pill for oral delivery of biotherapeutics: safety, tolerability, and performance in healthy subjects. , 2022). They found that 28 of the 31 pigs exhibited systemic drug uptake, and the plasma concentrations of all four drugs were similar to those obtained after intramuscular or subcutaneous injections. These percent bioavailability figures were comparable for the L-SOMA and subcutaneous methods, according to the team's calculations of the percentage of the GLP-1 peptide and insulin dose that entered the bloodstream. When administered via either a conventional injection or an L-SOMA, insulin caused a quick decrease in blood glucose, while adrenaline caused a quick rise in both blood glucose and heart rate.

IV. EXPERIMENTAL SECTION

The robotic pill was created by combining a number of parts, such as:

1) A 1.5 mm laser-cut optically clear cast acrylic sheet for the rigid backbone;

2) A 5μm cyclospora polycarbonate membrane (Whatman) that was manually cut from 1.5 mm plastic sheet and attached to the rigid backbone using double-sided adhesive medical (ARcare@90 445, Adhesives Research) tape in the shape of the rigid backbone;

3) A cylindrical neodymium magnet that was 3 mm in diameter and 1.5 mm thick (K&J Magnetics, 6451 Gauss); and

4) Sodium polyacrylate, which served as the absorbent materials. Measuring the Uptake of the Pill by Microparticles, Proteins, and Bacteria.

By mixing 10 mg of dry absorbent powder with 500μL of water, phosphate buffer saline (PBS), and gastric simulant, the material's absorption was assessed. For normalization, the weight of the collected solution was compared to the initial weight of the added solution (500μg) after the powder absorbed the solution.

To assess each component's capture contribution, the robotic pill was incubated in a 1 mL solution containing 2 μm microbeads (Spheritic, 465 ± 57 particles μL−1). Following the incubation period, the

robotic pill's rigid backbone, membrane, and absorbent material were all submerged in a 1 mL solution and gently rotated for 15 minutes. On a glass slide, 1μL of the supernatant was pipetted. The ability to collect was examined the robotic pill was incubated in 1% BSA solution in PBS for the entire night in order to perform protein analysis.

The absorbent material was collected, taken out of the robotic pill structure, and put in a container with either 2 m CaCl2 or PBS. Using micro-CA (Pierce) and the microplate standard technique, the amount of protein released from the absorbent medium was measured using samples that were diluted 1:10. Similarly, E. coli (ATTC, 25922GFP) was incubated with the robotic pill for an hour while being shaken at a starting concentration of ≈1.5 OD600 in order to measure bacterial uptake. After being taken out of the pill collector, the three absorbent gel matrices were each put in two milliliters of growth media to assess growth. From each tube, 200 μL was taken out every hour for 8 hours to quantify bacterial growth as measured using OD600 (Soto F, 2022).

Demonstration lozenge locomotion used an external glamours field

A 38 mm square neodymium attraction (K&J Magnetics) was placed 20 mm below a table substrate supporting the robotic lozenge to induce locomotion. A neodymium attraction was named as the glamorous core due to its glamorous field strength and penetration. The glamorous field strength was measured at different distances from the face of the attraction by a handheld movable digital tesla meter (TD8620, Tunkia). The attraction was rotated manually to beget the gyration of the robotic lozenge. The robotic lozenge was forced to walk across small monuments.

PREPARATION OF M-RNA LOADED ROBOTIPILLS, ADMINISTRATION IN GIT:

The SOMA robotic capsules can be used to deliver various macromolecules orally, in addition to mRNA. The oral delivery strategy has the advantages of superior convenience and case compliance.3 – 5 For illustration, Abramson et al. preliminarily described the oral delivery of insulins using the SOMA robotic capsules.6 In this study, the authors demonstrated the novel and creative design of the ingestible tone-orientating system- SOMA robotic capsules, which were inspired by the leopard tortoise's capability to passively reorient. therefore, orally conducted robotic capsules could fleetly reach the stomach and enable tone- exposure to the preferred upright position, allowing the injection of insulin- loaded tips into the mucosa within 1 min, which was touched off by the dissolution of caramelized sucrose. The insulin loads were also released to the mucosa within 1 h of the dissolution of the tips.

To expand the operations of the SOMA robotic lozenge system, Traverso, Langer, and their groups have enforced the oral delivery of systemic monoclonal antibodies, peptides, and small motes using a new interpretation of the SOMA robotic capsules. The new robotic capsules could n't only enable the oral delivery of medicines whose size range from small motes to monoclonal antibodies but also achieve a maximum medicine tube attention that's analogous to the standard- of- care subcutaneous injection within 30 min after the oral administration. Besides the SOMA robotic lozenge system, Traverso and associates have also developed numerous other smart biomedical biases for the oral delivery of birth medicines. Rather of delivering the rectifiers to the stomach apkins, a new robotic lozenge system called luminal unfolding microneedle injector (LUMI), exercising the tube- suchlike figure of the small intestine to give plenitude of points of contact with the apkins, was constructed to deliver rectifiers to the intestinal apkins. Upon oral administration, the elegant design of this robotic lozenge allows the rapid-fire propelling of dissolvable medicine- loaded microneedles, located on three unfolding arms, into intestinal apkins.

In another study, they designed a kirigami- inspired stent for the sustained delivery of rectifiers to the GI tract with minimal original medicine efficacity and minimum implicit systemic side goods.10 thus, a well- designed robotic lozenge system enables the oral delivery of mRNA to the GI tract, furnishing a simple and non-invasive approach for mRNA delivery, and might ultimately profit the rapid-fire development of new mRNA rectifiers and vaccines (Qiu D, 2016).

Evaluating the effects of coating the pill membrane:

The pervious membrane was carpeted with a EUDRAGIT L 100- 55(Evonik) using manufacturers protocols and drop cast over a pervious membrane containing a plastic glue in the shape of the robotic lozenge. The borders of the tenacious subcaste help to contain the enteric result in place. The material was left to dry overnight before use. UV green colour

(Bits power) was used to give discrepancy in the evaluation of the presence of enteric coating in the pervious membrane after incubation and as an index captured result. The membranes and capsules were placed in either dissembled gastric fluid simulant (Ricca) or buffer result (Tao W, 2022).

Demonstration lozenge locomotion used an external glamours field:

A 38 mm square neodymium attraction (K&J Magnetics) was placed 20 mm below a table substrate supporting the robotic lozenge to induce locomotion. A neodymium attraction was named as the glamorous core due to its glamorous field strength and penetration. The glamorous field strength was measured at different distances from the face of the attraction by a handheld movable digital tesla meter (TD8620, Tunkia). The attraction was rotated manually to beget the gyration of the robotic lozenge. The robotic lozenge was forced to walk across small monuments.

EXAMPLE OF ROBOTIC PILL FORMULATIONS

1.RANI PILL:

Diabetes type- I case without insulin pumps use a needle to fit insulin into their tummies about700 1000 times each time. A person with acromegaly receives a painful injection into the muscles once a month. In cases with multiple sclerosis, a disease slowing β-interferon medicine may be fitted three times per week in colourful spots of injection. Medical innovator Mr. Imran, Rani's author, president and CEO, has been working on a way to deliver large medicine motes for the once seven times. Rani rectifiers is developing a "robotic lozenge" which pledges to transport further delicate medicines past the stomach before releasing them into the bloodstream. A robotic lozenge that's designed to replaces the injections of large medicine motes including peptides, proteins and antibodies. Rani Pill is a effortless process due to the absence of pain receptors in the intestinal mucosa and they've shown emotional insulin bioavailability that's original to or better than subcutaneous injections. further than 100 beast studies testing the Rani Pill capsules and demonstrated 100 parts with injections. Taking the capsule made it easier for a case to take curatives that generally bear injections or infusions, like treatments for diabetes, arthritis, and other conditions. As soon as the capsules were swallowed, the levies were free to walk and bear typically for 30 twinkles, and an X-ray was taken every 30 twinkles to cover their progress. Rani blazoned in February 2019; a mortal safety study was completed (MS., 2021).

MECHANISM OF RANIPILL:

- The Rani Pill capsule enters into the intestine and when pH situations rise, the enteric coating of the capsule dissolves and a chemical response occurs (due to the mixer of citric acid and sodium bicarbonate) which inflates a balloon by the release of carbon dioxide gas.

- The pressure in the balloon pushes the dissolvable micro needle filled with the drug into the intestinal wall was represented in this.

- The Microneedle- predicated delivery may meliorate the bioavailability of a biologically active macromolecule. These micro needles containing bias in the gastrointestinal tract can pass safely. This study indicates that microneedle technology for use in the gastrointestinal tract is a successful bone

- The concave microneedles are composed of a drug force that is compressed through peristalsis, allowing the drug to be released through the needles. A solid microneedle system contains a drug formulated into the needles that pierce the kerchief and break incremental from the capsule.

- The needle expression enables the release of the drug in a controlled manner. Since the company is formerly working with proven

drugs, the main focus of Rani Pill's feedback was on demonstrating safety.

- A clinical trial must demonstrate that Rani Pill is as effective as a subcutaneous injection in absorbing the drug from the body. Imran says the way Rani Pill factory inside the body is similar to that of a robot, indeed though the device has no electronic factors.

2.ROBOTICPILLS CAN ORALLY DELIEVER LARGE DOSES OF BIOLOGICAL DRUGS:

Preclinical study evaluated treatments for diabetes, Crohn's disease, and other conditions that use injectable meds using an orally administered capsule: -

The study authors erected on former exploration where they developed robotic capsules that were able of delivering solid birth medicines into the systemic rotation via injection into the stomach and small intestine. These bias, estimated in beast models, accommodated lower medicine boluses (around half a milligram per capsule), which would bear frequent oral dosing for some generally used birth medicines. They also had limited immediate medicine immersion, precluding their use for fast- acting purposes (similar as mealtime insulin). "We applied assignments learned from our former work and developed a new device that can fit a concave needle into a shallow subcaste of the stomach filling, which allows for the delivery of liquid medicines."

Birth medicines so named because they're generally insulated from a living source, rather than chemically synthesized are used to treat a wide variety of conditions, including diabetes, seditious conditions, and certain types of cancer. still, due to their complex and fluently degradable factors, the administration of these medicines frequently requires a tone- injection, which can represent burdens for cases, similar as necessary training for proper tone- administration and the eventuality for needle stick injuries and pain. Now, NIBIB- funded experimenters are developing a robotic lozenge that, after swallowing, can deliver birth medicines into the stomach, which could potentially revise the way that certain conditions are treated.

He explained how their bettered device works in a domino- type fashion Once the lozenge has been swallowed and makes its way into the stomach, it uses its weighted bottom to orient itself duly, so that its injection medium is flush against the stomach wall. After many twinkles, a carbohydrate bullet at the top of the lozenge dissolves, cranking a spring and enabling a needle to fit the birth medicine into the stomach towel. also, an alternate, recently exposed bullet dissolves, freeing the spring and renouncing the needle back inside the lozenge, allowing for safe passage of the device through the gastrointestinal tract. "Combined with the fact that our capsule can deliver large boluses — over to four milligrams — of complex natural medicines, our robotic lozenge could have a transformative impact on cases who calculate on injectable specifics."

In order to assess if the robotic capsules could be ingested and passed through the gastrointestinal tract without difficulty, the experimenters estimated analogous robotic capsules (without any medicines) in eight tykes. They set up that all the creatures could ingest the capsule with ease, and radiographic monitoring revealed that the bias travelled to the stomach, actuated, and also travelled through the gastrointestinal tract as anticipated (Dhalla AK, A robotic pill for oral delivery of biotherapeutics: safety, tolerability, and performance in healthy subjects., 2022).

V. MERITS & DEMERITS

ADVANTAGES:

➢ The medicine absorbs truly snappily.

➢ Remains of the medicine are excreted within 1- 4 days.

➢ There are no substance, springs, or other factors in the expression.

➢ respectable safety and tolerability morals.

➢ The system is non- invasive.

➢ Increased acceptability by the case.

➢ Suitable for injectable birth drug oral administration.

➢ Suitable for the treatment of certain conditions, analogous as acromegaly and diabetes.

DISADVANTAGES:

➢ It's unhappy for specifics that need a advanced lozenge than the capsule can hold.

➢ Needs skill full persons.

➢ High priced.

➢ Lack of control over medicine release.

➢ Limited medicine storehouse capacity (Gao X, 2024)

LIMITATIONS AND CHALLENGES:

Humanized antibodies were used in the canine model in every study reported in this article. Acute decreases in serum drug levels, a marker of immunogenicity, indicate that some animals generated amounts of anti-drug antibodies during the drug measures period, even though none of the canine dogs in this study showed symptoms of an allergic reaction. Bioavailability was not calculated using data from these animals since doing so would have understated actual bioavailability. No matter how the drug was administered, immunogenicity or the formation of anti-drug antibodies took place. Although the results of this study show that oral and subcutaneous medication delivery had comparable bioavailability, the development of anti-drug antibodies suggests the canine.

The paradigm might not work well for humanized biotherapeutics in multi-day dosage studies. Furthermore, this study's findings were restricted to and concentrated on the pharmacokinetic parameters in order to facilitate PK-PD analysis, future research must concentrate on pharmacodynamic (PD) studies in an appropriate animal model.

Generally speaking, we showed that trans enteric distribution of biotherapeutics is quicker than typical subcutaneous injection in reaching the circulatory space. This result is similar to the quick adoption of trans-gastric delivery that Abramson Tal (2022) documented. In his time-course does not, however, account for the post-ingestion transit time from the stomach to the small intestine, where the RP capsule drug is administered. Furthermore, this study's findings were restricted to and concentrated on the pharmacokinetic parameters.

In order to facilitate PK-PD analysis, future research must concentrate on pharmacodynamic (PD) studies in an appropriate animal model. Generally speaking, we showed that trans enteric distribution of biotherapeutics is quicker than typical subcutaneous injection in reaching the circulatory space. This result is similar to the quick adoption of trans-gastric delivery that Abramson et al. (2022) documented. Physicochemical and biological elements are among those that affect the passage of medication tablets or capsules into the small intestine and stomach retention (Das et al., 2021). One of the physicochemical considerations is the dosage form's size. A hefty tablet or capsule, for instance, can have trouble getting past the pyloric sphincter and end up in the stomach for a long time.

The stomach retention period is also influenced by the dose form's shape. Passage may be made easier by a ring or round shape (Straubel et al., 2006; Parmar et al., 2014; Das et al., 2021). The system's density may have an effect on the stomach route as well. The subject's age is one biological component that influences the stomach retention time. According to Strobel et al. (2006), Parmar et al. (2014), and Das et al. (2021), a round or ring form may make passing easier. The system's density could also affect the transit of food. Age and other biological parameters have an impact on the stomach retention time. Compared to normal adults, young subjects exhibit faster stomach passage while elderly subjects exhibit slower gastric transit (Parmar et al., 2014). Regardless of height, body surface, or weight, males are more likely than females to have a faster gastric transit than females, in addition to subject age. A human trial assessed and documented the function of nutrition in the deployment of the RP capsule (Dhalla et al., 2000), and fed and unfed states are significant predictors of the stomach emptying time.

VI. APPLICATIONS

- Pill for oral delivery of biotherapeutics: -

The discomfort and inconvenience of frequent injections contribute to poor patient compliance and inadequate disease management, despite the high effectiveness of biotherapeutics. Oral biotherapeutic delivery is still ineffective despite multiple attempts because of intestinal absorption issues and GI environment degradation. We developed an oral robotic pill (RP) that stops the GI system from breaking down the biotherapeutic drug payload when it is administered.

The promising clinical results suggest that this versatile, oral drug delivery system could make it possible to safely and reliably distribute biotherapeutics that are currently administered parenterally (Singh A W. S.).

- Robotic pill for fluid sampling and biomarking in gastrointestinal tract: -

The early detection of gastrointestinal disorders may be enhanced by the development of on-site biomarker enrichment technology. Biomarkers or circulating signatures, including microorganisms, extracellular vesicles, nucleic acids, the secretin, and other indicators, are programmed with health-related data. These signals can be gathered and analysed by frequent sampling, which can serve as an early warning system for the development and course of disease. In order to examine body cavities, smart pills have been used. For example, the PillCam is a camera-equipped ingestible capsule that is commonly used to detect GI polyps.

- Insulin for oral drug delivery: -

Oral insulin dose capsules and the Rani Pill have been developed to address the primary problem with injectable dosage forms for type I diabetes. Oral doses of insulin capsules and the rani pill are suitable for biologic hormone therapy in the treatment of diseases such as acromegaly and diarrhoea caused by specific cancers.

An MIT (Massachusetts Institute of Technology)-led team has developed a medicine capsule that delivers oral insulin dosing. Insulin used orally can help people with type I diabetes who need injections by lowering blood sugar levels.

Additionally, it can be used to administer protein-based drugs, like immune suppressants for inflammatory bowel disease and rheumatoid arthritis. Oral insulin dosages can help diabetic patients with poor glycaemic control, clinical issues, psychosocial comorbidities, or poor mental health.

These studies mostly concentrate on the self-orientation property of macromolecules, which is supported by in vivo research that revealed that over half of adults with insulin dependence forego subcutaneous injections, a behaviour associated with patient non-adherence (Fu AZ, 2009).

- Robotic capsules for intestinal illness monitoring, diagnosis, and therapy: -

When PillCam, the first commercial capsule endoscope, was introduced in 2001, it completely changed GI diagnosis. Simple non-invasive pill swallowing without anaesthesia is its defining feature, offering a fresh substitute for the GI endoscopic visualisation technique. Nowadays, disorders in different areas of the GI tract can be found via capsule endoscopy. Researchers have worked hard to create multipurpose smart capsule robots in response to the quick development of targeted medicine delivery. Generally speaking, the majority of capsule robots can be divided into two groups: those that use microelectromechanical systems and those that incorporate non-mechanical technologies. Anchoring the non-mechanical system, the interaction between the external magnet and the permanent magnet inside the capsule provides remote drive for the controllability of the drug release and capsule position (Wei X, 2024).

- Moving towards multipurpose robotic tablets: -

Together with the multifunctionality, growing miniaturisation, and sophistication of micro robotic systems, robotic pills take advantage of the benefits of oral pharmaceutical formulations, specifically their facile encapsulation, high loading capacity, ease of production, and high patient compliance.

Oral tablets with robotic capabilities based on microneedles, microinjectors, micro stirrers, or micro rockets. We contend that the realisation of complex multifunctional robotic tablets that function as closed-loop systems is made possible by the careful control of the release properties of their payload in conjunction with the integration of numerous micro robotic functionalities into oral delivery systems.

- Safe Delivery of an Injectable Osteoporosis Drug by a Robotic Pill: -

Using a new “robotic pill,” a reliable and efficient osteoporosis drug that is presently only available as an injectable can be taken orally, according to a study presented.

When the robotic pill is swallowed, it passes through the stomach undamaged. The medication is administered by the pill's self-inflating balloon in the colon, which uses a micro syringe to inject a drug-filled microneedle

"The injection causes no pain because the intestines do not react to needles." Rapid dissolution of the needle allows the drug to be absorbed as the delivery system deflates and is safely expelled from the body.

VII. CONCLUSION

In conclusion, these original mortal clinical studies demonstrate the safety and performance of a protean, orally ingestible medicine delivery platform in healthy mortal levies. The RP was safe, well-permitted and delivered remedial quantities of

octreotide (a biotherapeutic) with an unknown bioavailability of 65, far exceeding the roughly 1 bioavailability with the current state- of- the- art remedy in oral biotherapeutic medicine delivery. The safety and trustability of the RP technology remain to be determined in larger, long- term studies with reprise administrations in chronically ill cases and across other demographics. nonetheless, it's noteworthy that in these single administration studies, there was no reported prevalence of pain or discomfort associated with the RP either during its deployment or during needle delivery, and all device remnants were safely and uneventfully excreted in all subjects. However, this innovative medicine delivery platform may offer an oral volition for numerous cases with habitual conditions presently taking frequent and painful parenteral injections If verified in larger case populations after reprise administrations with other biotherapeutic loads.

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