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Application Of Nanorobots In Medicine

Manisha Kasbe[1], Nishat Pathan[2], Rutika Barathe[2], Sakshi Kakade[2], Sakshi Labade[2], Maitreya Bhatkar[2]

[1]Assistant Professor, Department of Quality Assurance Techniques, Samarth College of Pharmacy, Belhe, Pune (Maharashtra), India,

[2]Department of Pharmacy, Samarth College of Pharmacy, Belhe, Pune (Maharashtra), India,

Abstract:

Nanorobots, an innovative and developing technology that combines robotics and nanotechnology, has great potential for revolutionising the medical industry. These tiny, self-contained machines, which are generally nanoscale in size, have the potential to precisely move through the human body, carrying out specific functions and dispensing medicines at the cellular and molecular levels. An overview of nanorobot applications in medicine is given in this abstract, with a focus on how they have the potential to revolutionise healthcare. Nanorobots are capable performing a wide range of tasks, including tissue regeneration, medication delivery, diagnosis, and surgery. They can be made to transport therapeutic agents or payloads of medications, enabling targeted, localised illness therapy. Drugs are delivered to the damaged location with the least amount of systemic adverse effects thanks to their capacity to travel through the circulation or enter tissues. Nanorobots with sensors and imaging equipment can diagnose illnesses quickly and with great precision by spotting their early symptoms. Nanorobots can reach difficult anatomical areas and execute minimally invasive treatments, considerably enhancing surgical techniques. They have the capacity to lessen patient suffering, healing time, and complication danger. Nanorobots can also help with tissue healing by moving and assembling biological components at the cellular level, which encourages regeneration processes. Nanorobots provide focused treatments and therapies in personalised medicine, providing promise for the treatment of diseases including cancer, neurological problems, and hereditary abnormalities. They have the potential to improve therapeutic effectiveness and lessen side effects by molecularly customising treatments. The creation and incorporation of nanorobots into clinical practise nevertheless face difficulties, despite these fantastic prospects. These concerns span a variety of areas, including as biocompatibility, power supply, safety, and navigation control. For nanorobots to be used safely and productively in healthcare, it is imperative that these issues be resolved.

Keywords: Nanorobots, Nanotechnology, Cancer Treatment, Surgery, Medicine,Healthcare, Gene Therapy,Component, Nano-surgery, Disease Management.

INTRODUCTION

Chemistry, physics, materials science, and biology are all combined in nanotechnology to create ground-breaking innovations. This multidisciplinary method makes it possible to control matter at the nanoscale, opening the door to revolutionary developments in industries like electronics and medicine [1]. Small, specialized nano-devices called nanorobots are made to function at nanoscale dimensions, usually between 1 and 100 nanometers. Their main goal is to protect or restore the human body by carrying out accurate duties, frequently focusing on infections, and administering medicines with exceptional precision. These tiny devices have the potential to completely transform healthcare by providing highly accurate and efficient molecular therapies [2]. In both the medical and industrial areas, they are projected to work at the atomic, molecular, and cellular levels. Nanorobot medication delivery systems are becoming a reality thanks to developments in robotics, nanostructuring, medicine, bioinformatics, and computers. A variety of specialist nanorobots, including Respirocyte nanorobots, Microbivore nanorobots, Surgical nanorobots, and Cellular Repair nanorobots, are included in these state-of-the-art systems. These microscale wonders, whose widths typically vary from 0.5 to 3 microns, are painstakingly put together from parts ranging in size from 1 to 100 nanometers. They have the potential to revolutionize drug delivery by working at the cellular and molecular level, bringing about more accurate, targeted, and efficient medical interventions that may change the way healthcare is provided in the future [3]. The wave frequency of signal ranges between 1-100 MHz.

COMPONENTS OF NANOROBOTS

Various components in nanorobots includes

Nanobearings and nanogears:

Ball-and-stick models or space-filling models can be used to depict bearings and gears. In this instance, silicon, oxygen, and hydrogen are also included in the 206 carbon atoms that make up the bearing. A tiny shaft with a diameter of 2.2 nm is used in the design, and it spins inside of a ring to reduce friction and enable smooth shaft rotation. The molecular gear mechanism is a small, 4.3 nanometer-diameter structure that is part of the nanoscale. It is made with a silicon shell ended with sulfur atoms, has 12 moving components, and a molecular weight of 51009.84 Daltons. These specifics highlight its complexity and possible nanotechnology uses for precise molecular-level processes [4].

Payload:

The nanorobot carries a drug in a void section and, when inside the body, releases the drug at the targeted site of action [5].

Micro-camera:

Nanorobots move through the circulatory system by the control and monitoring system, which also keeps checks on their performance [6].

Electrodes:

Electrodes that can use ions from biological fluids to build a battery can be used for both tumor therapy and other purposes. The precise electric currents delivered by protruding electrodes might target and perhaps destroy tumor cells. Surface electrodes, meanwhile, provide regulated application for the elimination of tumors. Although further study and medical oversight are needed for its safety and effectiveness, this novel strategy shows promise [7].

Laser:

Hypothetical nanorobots with integrated lasers are utilized in medical procedures including the removal of blood clots and plaque in the arteries. The laser systems on these nanorobots would be able to accurately target and remove blood artery barriers, so restoring blood flow [6].

Ultra-sonic signal generator:

It's a novel idea in the world of medical therapy to employ ultrasonic noises along with nanorobots to remove kidney stones. With this strategy, nanorobots that can travel the urinary system and locate kidney stones would be used. The use of ultrasonic waves might help the body naturally eliminate kidney stones by dissolving or breaking them down into smaller, more readily accessible bits [8].

Swimming tail:

Nanorobots use a variety of transportation techniques to penetrate the body. They move using motors and, occasionally, manipulator arms or mechanical legs for greater mobility in the challenging environment. Their control systems are run by specialist software created to mimic and govern the behavior of nanorobots in fluid environments with Brownian motion's unpredictable motions. Nanorobots are extremely useful for medical applications since they can identify target molecules thanks to their chemical sensors. Ant colony optimization (ACO), artificial bee colony (ABC), and particle swarm optimization (PSO), three main swarm intelligence techniques, are harnessed to enhance their collective intelligence and adaptability, promising to revolutionize healthcare by performing precise and effective tasks inside the human body. Nevertheless, as this technology develops, addressing safety, control, and ethical issues becomes essential [11].

Nanocomputers:

In fact, having some kind of internal processors is essential for effective nanorobot activity within the human body. These tiny computer systems act as the brains of nanorobots, giving them the ability to carry out precise, focused activities inside the complex atmosphere of the human body [9]. These onboard computers provide control and real-time monitoring of these small devices, making them useful tools for doctors.

Physicians can improve the accuracy and effectiveness of medical treatments by programming nanorobots to go through blood veins or tissues, deliver medications to precise areas, or repair damaged cells. These computers' connectivity capabilities allow medical professionals to monitor the progress of the nanorobots and make necessary changes [10].

APPLICATION OF NANOROBOTS

Application of Nanorobots in Dentistry:

Nanorobotic Dentifrices (Dentifrobots): Dentifrobots have the ability to completely transform oral health when used in toothpaste or mouthwash. They are capable of successfully covering subgingival surfaces and vaporizing trapped organic materials. These tiny mechanical tools are also made to recognize and get rid of harmful germs that are prevalent in plaque and other parts of the mouth. They are significant in that they self-deactivate when eaten, guaranteeing safety. A potential new direction for more thorough, least intrusive dental treatment is provided by this breakthrough [12].

Maintenance of Oral Hygiene: The future of oral health could be found in a cutting-edge mouthwash that contains intelligent nanorobots. These nanorobots are made to recognize and get rid of unwanted bacteria, creating a balanced environment for healthy oral flora. Additionally, they improve oral hygiene by spotting and removing food particles, plaque, and tartar from the teeth. They can access places that conventional toothbrushes and floss can't, resulting in a more complete cleaning because to their liquid suspension. Additionally, sub-occlusal nanorobots that are provided by dental products help to prevent halitosis and serve as a constant barrier against tooth decay. With the use of this technology, dental treatment might become more efficient and convenient [13].

Cavity Preparation and Restoration: For cavity preparation and tooth restoration, several, invisible-to-the-eye nanorobots might be deployed. In order to preserve the maximum amount of healthy tooth structure, cavity preparation is very strictly limited to the demineralized enamel and dentin [12].

Tooth Repair: The latest way of handling serious tooth repair is nanodental technology. To repair injured teeth, these methods combine tissue engineering, genetic engineering, and tissue regeneration approaches. Nanorobots are essential to this approach because they allow for full dentition replacement treatment. They are able to regenerate cellular structures in addition to replenishing the mineral components of tooth. This all-encompassing strategy presents a promising road to more efficient and sophisticated dental treatments [13].

Dentin Hypersensitivity: Pressure is transferred hydrodynamically to the tooth pulp and results in dentin hypersensitivity, a painful dental ailment. The development of reconstructive dental nanorobots, which can quickly and precisely obstruct certain dentinal tubules, has proven to be a game-changing answer. With the use of this ground-breaking technology, patients may treat dentin hypersensitivity quickly and effectively, thus enhancing their quality of life and comfort with their mouths [14].

Esthetic Dentistry: Nanorobots are essential to dental renaturalization techniques in cosmetic dentistry. They are able to remove outdated amalgam fillings and repair teeth using biological materials so that the new teeth seem exactly like the old ones. With the use of this cutting-edge method, dental restorations are made to closely resemble the appearance and functionality of teeth in their natural state, enhancing both aesthetics and patient happiness [13].

Tooth Repositioning: Nanorobots for orthodontics are a great development in dental treatment. They are capable of directly manipulating alveolar bone, cementum, gingiva, periodontal ligament, and other periodontal tissues. With the help of this ground-breaking technology, teeth may be rotated, straightened, and vertically repositioned quickly and with little to no discomfort. With the help of this invention, orthodontic treatments may become more effective and patient-friendly [14].

Inducing Anesthesia: A colloidal solution containing millions of functional, analgesic, micron-sized dental nanorobots will transform dental treatment in the future. These small devices are applied to the patient's gingiva, where they come into touch with the mucosa or crown and move to the dentin. It is amazing how gently they pass through the lamina propria or a tiny layer of loose tissue at the CEJ to cross the gingival sulcus. With the use of this technology, patients might experience less pain throughout less intrusive and more effective dental operations. These nanorobots can pierce the dentinal tubules to a depth of 1-4 m after they have made it to the dentin, at which point they can continue on their way to the pulp. Chemical gradients, temperature changes, and positional navigation under the supervision of a nanocomputer direct their course. Nanorobots can go from the tooth surface to the pulp in under 100 seconds thanks to this amazing technology, demonstrating its promise for quick and accurate dental procedures. The level of accuracy and comfort of patient treatment have improved significantly because to the introduction of analgesic nanorobots in dental care. These nanorobots take over the regulation of nerve impulses after they are implanted in the pulp. They may swiftly and arbitrarily turn off all sensitivity in a particular tooth that needs treatment when instructed to do so by the dentist. The dentist may immediately numb the selected tooth with a portable remote, doing so without the need of needles. The dentist may tell the nanorobots to restore full sensation when the treatment is finished, and then lead them out of the tooth. This method to nanorobot analgesia has a number of benefits, including improved patient comfort, less anxiety, more selectivity and controllability of analgesic effects, quick and fully reversible action, and avoidance of problems and adverse effects.

Nanorobots in heart surgery:

You have succinctly outlined the problem of fatty material accumulation producing reduced blood flow in the coronary arteries, which results in heart attacks and organ damage. The current surgical procedures utilised to treat these issues are angioplasty and heart bypass surgery. These operations are designed to stop coronary artery constriction and restore healthy blood flow to the heart. The surgery known as coronary artery bypass grafting (CABG) is used to treat coronary artery disease, which is characterised by the narrowing of the arteries that supply the heart muscles with oxygen and nutrients. In CABG, a graft made from an autologous vein—typically taken from the patient's leg or chest—is used to produce bypasses that travel around these coronary arteries' blockages or constrictions. Although CABG is a successful treatment for this illness, there is a chance for consequences. This surgical procedure may have unfavourable outcomes, such as obesity, sternal wound infections, leg infections, and atrial dysrhythmias. To reduce these risks and guarantee the best patient results, careful preoperative assessment and postoperative treatment are important [15]. The centre of the chest is where incisions are done during CABG surgery. In comparison to the average national rate of 6.2%, the worldwide mortality rate is 12.1% [16]. Coronary artery bypass grafting (CABG) is the name of the open-heart procedure that you're discussing. Commonly known as a median sternotomy, it entails creating an incision down the centre of the chest. A leg vein is extracted during this treatment and used as a transplant, often the saphenous vein. This vein has an aortic connection at one end and a coronary artery connection at the other. With the help of this surgical procedure, the coronary arteries' obstructions or narrowings will be bypassed, allowing blood to flow once again to the heart muscle. The average time needed to accomplish this surgery is 4 hours [17]. It is true that there are hazards and restrictions associated with the use of conventional procedures for treating problems like plaque accumulation in blood vessels. The use of nanorobots has become a viable option in the search for safer and more efficient medical procedures. With nanorobots, many of the hazards connected to conventional operations might be reduced. These tiny devices have the advantages of speed and accuracy in addition to being safe for use within the human body. They provide a cutting-edge method for dealing with problems including plaque buildup in blood vessels. It may be possible to provide tailored, less invasive medicines using nanorobots, lowering risks and increasing patient outcomes [18].

Nanorobot characteristics and components for heart surgery

These nanorobots feature two surfaces. While the vacuum-sealed inside surface is kept separate from liquids, the external surface communicates with the body's surroundings and chemical constituents. Leukocyte immune reaction is prevented by the passive diamondoid's biocompatible, perfect shell. The exterior's minimal bioactivity and chemical inertness increase safety and efficiency. The precise and less invasive medical uses of this cutting-edge design are promising. An electric motor helps these nanorobots move within, while microprocessors control how they behave overall. A radioactive substance is incorporated onto their exterior in order to monitor their whereabouts inside the circulatory system[19]. A magnetic switch is also included, enabling the activation and deactivation of their bodily processes as required. For a variety of medical applications, this technology combination offers precise and regulated actions[19].

Nanorobot introduction into the circulatory system

In order to provide effective access to multiple places in the shortest amount of time, nanorobots are often injected into the body through bigger diameter blood arteries. The arterial system in the leg is frequently the first option for this use[20]. This artery provides simple access to the systemic circulation, enabling efficient distribution of nanorobots to critical locations. Because it is easily accessible and close to numerous bodily areas, it is particularly useful for treatments needing connections to the bloodstream[19].

Circulatory system activity with nanorobots:

The nanorobots include implanted active propellers that allow for internal mobility within the body. These propellers are propelled by electric motors with shrouded blade structures that are vital for limiting tissue injury in the case of unavoidable accidents. Through careful planning, the nanorobots may move through the body with little disturbance to the sensitive biological environment [21].

Moving in the direction of the plaque

The nanorobots have both long-range and short-range sensors to discriminate between desired and unhealthy cells. In order to locate plaques precisely, long-range sensors are used. Along with the nanorobots, a radioactive fluid is also injected into the bloodstream. It travels in the same direction. The precise position of the nanorobots within the circulatory system may be determined with the help of this fluid [20]. The nanorobots may efficiently target and handle certain regions of concern by combining various technologies, doing so with the least amount of harm to healthy cells. A mixture of tracking techniques, including fluoroscopy and radiosensitive imaging devices, are used to accurately find and move nanorobots throughout the circulatory system. A 3D map of the nanorobot's journey is created using this data. When reaching the desired spot, internal sensors check on the plaque while a TV camera provides accurate visual input. Changes in temperature are detected by short-range sensors, such as artery thermometers. The nanorobots are programmed with a maximum temperature fluctuation restriction. The nanorobots become active if the sensors notice a temperature change over this threshold. The spinning needle on these nanorobots destroys the particular problem location, enabling precise and regulated therapy [21].

Targeting the plaque

The activation of a revolving needle and a diamond-chipped burr is started after the nanorobot locates the plaque. Using this mixture, the plaque is broken up into tiny bits. In order to prevent the blade from damaging nearby healthy tissue while cutting, the operation is continually monitored by a camera. The resultant microparticles subsequently pass harmlessly through the circulation and are eventually eliminated from the body. With minimally invasive techniques, this approach provides a precise and regulated way to reduce plaque development[22].

Recovery from the body

The nanorobot must be taken out of the body once it has finished its intended task. The nanorobot is directed to a blood artery that is simple to reach from the outside of the body in order to assist this. After that, it can be removed with a quick surgical operation. This guarantees a secure and managed removal procedure, enabling the efficient application of nanorobots in medical procedures while reducing possible hazards[23].

In urgent situations

During nanobot-based medical procedures, a magnetic switch is employed as an on/off switch in emergency scenarios. The nanobot system is triggered and the nanorobots are started moving when a magnet is put across it for the first time. This magnetic switch ensures that the system stays active once it is turned on since it only works in one direction [24]. The surgeon may rotate the magnet bar in the opposite way to stop the activity of the nanobots, which essentially turns off the system and stops all continuing operations of these nanomachines. This magnetic switch offers a prompt and dependable way to manage and stop the nanobot operation as needed [25].

Nanorobots in Kidney Disease: Nanorobots have the potential to completely change medicine, particularly renal disease therapy. Here are various applications for nanorobots in the context of renal disease [26].

Targeted Drug Delivery: Drugs or therapeutic substances can be delivered to the kidneys selectively via nanorobots. The efficiency of therapies may be increased while negative effects to other sections of the body are reduced because to this tailored medication administration. This might involve administering drugs for high blood pressure, an infection, or inflammation straight to the regions that are damaged in the case of renal disease [26,27].

Kidney stone removal: Kidney stones can be extremely painful and complicated. Kidney stones might be broken down or removed more accurately and with less harm to the surrounding tissue if nanorobots were equipped with microscopic tools[28].

Renal Tissue Repair: The injured kidney tissue may be repaired with the help of nanorobots. They might be designed to promote tissue regrowth or treat certain kidney lesions brought on by trauma, infection, or disease [28].

Diagnostics: The condition of the kidneys might be continually monitored by nanorobots with sensory capabilities. They might evaluate filtration rates, check blood levels of certain chemicals, or look for early indications of kidney illness, providing crucial information for early diagnosis and treatment [29].

Blood Filtration: Nanorobots could help in blood filtration in renal failure situations. They could function as improved or artificial filtration systems, assisting in the removal of waste and extra fluid from the blood [30].

Immunotherapy Support: For autoimmune kidney diseases like lupus nephritis, nanorobots could enhance immunotherapies by regulating immune responses and suppressing inflammation within the kidneys [30].

Genetic Therapy: Some kidney diseases have a genetic basis. Nanorobots could be used to deliver gene-editing tools to correct genetic mutations associated with kidney disorders [31].

Toxin Removal: Certain kidney diseases can be caused or aggravated by the accumulation of toxins in the body. Nanorobots might help in removing these toxins from the bloodstream more efficiently[32].

It's essential to remember that theoretical and experimental research still dominates the field of using nanorobots to treat renal problems. There are several technological, safety, and regulatory obstacles that would need to be surmounted before nanorobots could be developed and used in therapeutic settings. However, there are major advantages to adopting nanorobots in kidney disease research since they could result in more efficient and minimally intrusive therapies with better patient results[33].

Nanorobots in Gout: Here are some potential applications for nanorobots in the treatment of gout.

Uric Acid Removal: Nanorobots could be designed to identify and selectively remove uric acid crystals from affected joints, potentially reducing pain and inflammation associated with gout [34].

Drug Delivery: Nanorobots could be used to deliver medication directly to the affected joints, allowing for precise dosing and minimizing side effects[35].

Anti-Inflammatory Action: Nanorobots could be programmed to release anti-inflammatory agents at the site of inflammation, helping to reduce the painful symptoms of gout [34].

Diagnostic and Monitoring: Nanorobots equipped with sensors could be used to monitor uric acid levels in the bloodstream and provide real-time feedback to healthcare providers and patients [36].

Application of nanorobots in cancer treatment: The subject of cancer treatment holds great potential for nanorobots, also known as nanobots. Researchers are looking at numerous possible uses for nanorobots in the detection, management, and therapy of cancer, despite the fact that this technology is still mostly in the experimental and theoretical stages. Here are some of the main applications for nanorobots in cancer treatment[37].

Early Detection and Diagnosis: Nanorobots can be designed to detect specific biomarkers associated with cancer in the bloodstream or at the tissue level. They could serve as highly sensitive and specific diagnostic tools, allowing for earlier and more accurate cancer detection [38].

Drug Delivery: One of the most promising applications of nanorobots in cancer treatment is targeted drug delivery. Nanorobots can be engineered to carry and release chemotherapy drugs or other therapeutic agents directly to cancerous cells. This targeted approach minimizes damage to healthy tissues and reduces side effects associated with traditional systemic chemotherapy [39].

Precision Medicine: Nanorobots can be programmed to deliver a combination of therapies tailored to the specific genetic and molecular characteristics of an individual's cancer. This is a crucial aspect of precision medicine, allowing for personalized treatment strategies[38].

Tumor Microenvironment Modification: Nanorobots can be designed to modify the tumor microenvironment by delivering agents that suppress tumor growth factors, inhibit angiogenesis (formation of blood vessels that feed the tumor), or promote the immune system's response to cancer cells [40].

Surgery Assistance: Nanorobots could be used to assist surgeons in performing minimally invasive procedures. They could navigate within the body to reach and treat cancerous lesions with precision, reducing the need for open surgeries [38].

Monitoring and Imaging: Nanorobots equipped with sensors and imaging technology can provide real-time monitoring of cancerous lesions. They can help assess treatment response and detect early signs of tumor regrowth [41].

Removal of Cancerous Cells: In some cases, nanorobots may be designed to physically remove or destroy cancerous cells, either by mechanical means or by inducing apoptosis (programmed cell death) [39].

Hyperthermia Therapy: Nanorobots could generate localized heat (hyperthermia) in cancer cells to destroy them. This approach is known as thermotherapy and can be used as a complementary treatment alongside other cancer therapies [42].

Application of nanorobots in diabetic patients: Despite being mostly theoretical and experimental, nanorobots have the potential to provide ground-breaking solutions for the prevention and treatment of diabetes. The following are some possible uses of nanorobots for diabetic patients[43].

Blood Glucose Monitoring and Regulation: Nanorobots could be designed to continuously monitor blood glucose levels with exceptional precision. They could provide real-time data on glucose fluctuations and, when necessary, release insulin or other glucose-regulating medications to maintain blood sugar within a healthy range. This could greatly improve diabetes management by reducing the need for constant self-monitoring and manual insulin injections[44].

Drug Delivery: Nanorobots can be employed to deliver insulin and other antidiabetic medications directly to the target cells in a controlled and precise manner. This eliminates the need for multiple injections, enhances medication efficacy, and reduces the risk of hypoglycemia[45]

Pancreatic Regeneration: In type 1 diabetes, where the pancreas doesn't produce insulin, nanorobots could potentially be used to stimulate the regeneration of insulin-producing beta cells. They might also protect existing beta cells from autoimmune destruction in autoimmune diabetes[44].

Tissue Repair and Healing: Diabetes can lead to complications like poor wound healing and tissue damage. Nanorobots could be designed to accelerate wound healing by delivering growth factors or by directly repairing damaged tissue [45].

Infection Control: Diabetic patients are often more susceptible to infections due to compromised immune function. Nanorobots could help combat infections by delivering targeted antimicrobial agents to infected areas or enhancing the body's immune response [44].

Sensing and Alert Systems: Nanorobots can be programmed to detect early signs of diabetic complications such as neuropathy or retinopathy. They could then relay this information to medical professionals for early intervention[45].

Customized Treatment: With advances in precision medicine, nanorobots can be tailored to an individual's specific diabetic profile, providing a personalized treatment plan based on genetics, lifestyle, and other factors[46].

Diagnostics: Nanorobots may be used for diagnostics by detecting specific biomarkers associated with diabetic complications or related health issues, providing early warnings and facilitating timely treatment[44].

NANOROBOTICS IN GENE THERAPY

In the field of gene therapy, nanorobots have the potential to be a game-changer since they provide novel strategies for locating, modifying, and controlling the genes that are present in a patient's cells. These tiny robots may be painstakingly configured to carry out a number of essential tasks in gene therapy. In the first place, nanorobots allow for extremely accurate gene delivery, guaranteeing that therapeutic genes reach their targeted locations with outstanding accuracy and reducing off-target consequences. Additionally, gene-editing tools like CRISPR-Cas9 may be added to nanorobots, allowing for the repair of genetic mutations, the insertion of therapeutic genes, or the fine-tuning of gene expression [47]. When differentiated cells are reprogrammed into other cell types for regenerative purposes, they play a part in the process. By delivering small interfering RNA (siRNA) or antisense oligonucleotides, nanorobots can also help temporarily silence genes, regulating the expression of particular disease-related genes. In tissue regeneration, their capacity to direct stem cell differentiation is crucial. Nanorobots with sensors also offer real-time monitoring of the effects of gene therapy, enabling quick treatment modifications depending on feedback. This accuracy not only improves the safety of gene therapy but also pave the way for highly customized therapies catered to the unique genetic profiles of each patient [43]. Although nanorobots in gene therapy are still mostly in the experimental stage, they show great potential for future, more precise and successful genetic treatments. Despite this, there are still issues with biocompatibility, safety, and successful navigation within the human body. Before general acceptance in clinical practice, regulatory clearances and clinical studies will be important milestones[39].

FUTURE SCOPE

Nanorobots have the potential to make significant improvements in the field of medicine. These little, exact technology have the potential to fundamentally change diagnostics, targeted medicines, surgical operations, and regenerative medicine. As technology develops, nanorobots could be essential for early diseases diagnosis, individualised treatment plans, and even distant medical operations. They will be even more effective at improving patient care and transforming the medical industry as a result of their integration with artificial intelligence and the creation of regulatory frameworks. To fully realise their promise in healthcare, however, issues with safety, control, and ethical considerations must be resolved.

CONCLUSION

The use of nanorobots in medicine is an exciting new field that has the potential to completely transform patient care, diagnosis, and therapy. They are useful tools in fields including medication delivery, early illness diagnosis, and regenerative medicine because of their accuracy, minimally invasive design, and multipurpose capabilities. It's crucial to recognize that there are still major obstacles to overcome in terms of biocompatibility, safety, and regulatory clearances. The area of nanorobotics provides the potential for future medical procedures that are more efficient, individualized, and minimally intrusive.

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