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Revolutionizing Early Disease Detection: The Role of Nanodiagnostics in Modern Healthcare.

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Abstract- ***The modern world's rapid pace has created a number of difficulties for the healthcare industry. Several infectious diseases, cancers, high blood pressure, diabetes, and depression are among the frequent consequences linked to the fast-paced, high-stress lifestyle. For these medical conditions to be promptly arrested and managed, early diagnosis has been the aim. These days, this has been difficult. But in times like these, significant scientific progress with enhanced potential for medical diagnosis has also been a huge step forward. A new area of laboratory medicine called nanodiagnostics has helped to develop better imaging of internal body structure, early disease detection even before symptoms appear, and ease of diagnostic procedures. Current methods being developed for use in nanodiagnostics include the use of microchips, biosensors, nanorobots, nano identification of single-celled structures, and microelectromechanical systems. This article presents a broad overview of the current state of nanotechnology advancements in medical diagnosis while speculating about future prospects and opportunities for better health care delivery.***

Index Terms- Biosensors, Imaging Techniques, Nanodiagnostics, Nanorobots

I. INTRODUCTION

The idea of nanotechnology has been at the forefront of scientific research recently, despite the fact that the creation and application of the smallest particles that are invisible to the human eye are not particularly novel. It has been determined that the phenomenon that causes the ancient Roman glass cup to reflect various colors when illuminated is caused by colloidal nanoparticles of gold and silver. The elasticity and resistance noticed in the legendary Damascene Sword have been described to be due to nanometer sized particles of carbon discovered to be present in them.[1] The use of nanoscale particles to produce results, track processes, and participate in reactions has been both intriguing and exploratory in a variety of fields, including the physical, environmental, and even biological sciences. Since components of functional biological units like deoxyribonucleic acid (DNA), ribosomes, and ribonucleic acids in living cells, for instance, are primarily of nanoscale sizes, nanotechnology becomes increasingly relevant in the life sciences. This offers the possibility of using nanotechnology to screen for flaws in these cell components, detect them, enhance, and integrate them.

According to the United States Environmental Protection Agency, nanotechnology is the branch of science that uses nanoscale particles, studies their unique characteristics, and uses them to achieve desired results in the fields of engineering, medicine, agriculture, or pharmaceuticals. It involves the creation and use of structures, devices, and systems that have novel properties and functions due to their small and/or intermediate size. Nanoparticles are the subject of nanotechnology. A nanoparticle is any material that has dimensions smaller than 1 µm. Numerous practical instruments have been made available by nanotechnology for the detection of biomolecules and analytes that are important for diagnostic purposes (nanodiagnostics)[2]. Understanding nanoparticles and their special characteristics helps one to understand the odd justifications for their use.

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A contemporary method of medical testing that is carried out in close proximity to the patient's care is Point-of-Care (POC) diagnosis. At the time of need, it seeks to offer quick, precise, and real-time medical condition detection. In recent years, POC diagnostics have drawn more attention, especially in clinical medicine where on-site detection is highly desired, particularly in resource-constrained areas. As a result, numerous techniques, tools, and biosensors have been developed to meet the demand for POC diagnostics..[3]

Clinical applications such as tissue engineering, drug delivery, bioimaging, and diagnostics have advanced thanks in large part to nanotechnology. Because of their unique characteristics, including their potential for point-of-care testing, increased sensitivity, and quick detection, nanodiagnostics have attracted a lot of attention in the field of infectious diseases. The development of new and efficient nanodiagnostics for infectious diseases holds promise for the development of portable, reliable, and reasonably priced point-of-care (POC) diagnostic platforms for the detection of infectious diseases in underdeveloped nations.[4]

POC diagnostic technologies must be portable, inexpensive, easy to use, and disposable in order to be successful. They ought to be able to analyze tiny amounts of bodily fluids, including urine, saliva, and blood. Cost is a significant consideration for applications in global health, and efforts should be made to lower costs by utilizing few, costly reagents, low-cost manufacturing techniques for large-scale production, and maintaining quality control. For the development of portable POC diagnostic devices, miniaturization is also essential. Moreover, the environmental conditions of resource-limited settings, such as insufficient water, unreliable electricity, high temperatures, and humidity, should be considered for the clinical use of medical diagnostic devices.

Nanoparticles :

Because of their special properties, nanomaterials and nanostructures can be used to create nano diagnostic platforms that can quickly and accurately identify diseases from small amounts of patient samples. The high surface area to volume ratio of nanoparticles, which enables dense molecular coverage, is one of their main advantages. Because of this characteristic, disease biomarkers can bind to multiple sites, increasing the specificity and sensitivity of bioassays through a Mult effect.

Medical textbooks have used a variety of catchy phrases to describe medical diagnostics. However, encapsulating the primary idea, the homepage of the Journal of Medical Diagnostic Methods website, slightly modified, defines it as the field or practice of diagnosis that entails identifying and characterizing a disease state and the factors that contribute to it using a variety of diagnostic techniques and signs and symptoms gleaned from patient history or physical examination of patients or their specimens. Finding out what medical condition is being treated, managed, or endured is crucial. This is particularly true given that diagnosing a medical condition is the first step in any treatment or management effort. Therefore, medical diagnosis has a long history, starting with the rudimentary organoleptic evaluation of body samples and continuing through the use of microscopy, biosensors, and body imaging. Therefore, using nanotechnology to enhance diagnosis is a positive step.

The new term "nano diagnostics" refers to the application of nanotechnology's principles and methods for diagnostic purposes. It involves reducing the size of systems and platforms to utilize nanoscale properties obtained from interactions between surfaces and biomolecules, as well as manipulating and evaluating individual molecules, among other things. In order to meet the demands of clinical diagnostics, identifying the pathology of the condition, determining the disease state, identifying any predisposition to it, and identifying the causative organisms, nano diagnostics is an emerging application of nanoscale technology. Diagnostics are being performed on a nanoscale thanks to nanotechnology, which has led to a trend toward the use of portable, user-friendly, and commercially viable devices. As a rapidly developing area of molecular diagnostics, nano diagnostics has been improving laboratory processes by offering new methods for evaluating patient samples and early, more sensitive, and more specific identification of disease biomarkers. Since most complex procedures are now integrated onto a single, easy-to-use device that can be used for on-the-spot diagnosis, nanoparticle platforms have been developed and optimized for the detection of pathogens and cancer biomarkers, making diagnostic procedures less laborious but more sensitive. Nanomedicine for tumors of the digestive system: Common malignant tumors of the digestive system include colorectal, gastric, esophageal, liver, pancreatic, and other cancers of the digestive organs. The number of new cases and deaths from digestive system tumors is predicted to rank first among all tumors in the United States in 2023, based on the most recent cancer statistics. The majority of colorectal cancers start from cancer stem cells (CSCs) in colorectal inner wall polyps, which are the accumulation of genetic and epigenetic variations. Colorectal cancer is the second most common cause of cancer-related deaths. Liver cancer ranks fourth in terms of cancer-related deaths and sixth in terms of global cancer incidence. Chronic hepatitis B and hepatitis C viruses, excessive alcohol consumption, aflatoxin infection, smoking, type II diabetes, obesity, and other conditions are the main risk factors. Known as the "king of cancers," pancreatic cancer is one of the most difficult malignant tumors to treat worldwide, with a 5-year survival rate of less than 9%. Pancreatic cancer is predicted to rise to the position of the second most common malignant tumor in the world by 2030. Esophageal and gastric cancers are the sixth and fifth most common types of cancer globally, respectively. More than half of all esophageal cancer cases are reported in China, and gastric cancer has the second-highest death rate after lung cancer.

Tumors of the digestive system can now be better treated with traditional therapy (chemotherapy, radiation, and surgery), but there are still a number of negative effects, such as toxicity and drug resistance to healthy cells and tissues. The development of a new therapeutic strategy that can increase treatment effectiveness and reduce the likelihood of side effects is desperately needed.

Nanotechnology has advanced significantly in recent decades and has been extensively employed in the study of tumors of the digestive system. This includes the use of NPs, dendrimers, liposomes, polymers, light-triggered therapy, and nanotechnology in combination for diagnosis or treatment.

Diagnosis:

Similar to other forms of cancer, the detection of tumor biomarkers and the application of imaging methods are key components in the monitoring and diagnosis of cancers of the digestive system. Blood biomarkers are primarily used for early tumor detection, but the majority of the biomarkers disappear from the tumor. The secreted biomarkers become diluted after blood circulation, which results in a lack of specificity. CT, MRI, colonoscopy, endoscopic ultrasonography (EUS), and other imaging techniques are examples. Low sensitivity is one of their common issues, though. Enhancing biomarker detection specificity, improving imaging effect, imaging time, and targeting, achieving local tumor aggregation, and lowering non-specific interference are all clear benefits of nanotechnology.

A very sensitive and precise technique for detecting tumors is a nano sensor. A multi-protease nano sensor for exogenous drug release was created by Loynachan et al. The AuNC-NAV complex, which is stable in vivo without interference and maintains catalytic activity, is created by the sensor using the renally cleared catalytic AuNCs as the template and coupling them with a neutral avidin protein scaffold via a biotinylated protease-cleavable peptide connector. Zinc-dependent matrix metalloproteinase 9 (MMP9) and serine protease thrombin were among the proteases that caused its disassembly in the diseased site. Among these, MMP cleaved the MMP-responsive AuNC-P2 20-NAV nanosensor in the tumor site with abnormally elevated MMP expression, releasing AuNC that was roughly 2 mm in size. The ability of AuNC to catalyze peroxidase substrate was used to easily and sensitively determine the disease status after AuNC was released into the urine through renal filtration. The findings demonstrated that colon cancer mice had a stronger urine colorimetric signal than healthy mice, and that protease activity monitoring was able to overcome the biomarkers' lack of specificity. However, the nanosensor is not toxic and can be removed by renal excretion. Hepatocellular carcinoma frequently exhibits the up-regulation of important biomarkers, and individual variations are substantial. Multiple biomarker detection with high sensitivity is crucial for the early identification and diagnosis of liver cancer. Tang et al. created a SERS-responsive silver nanoparticle film based on the enhanced Raman scattering (SERS) frequency shift immunoassay. This increased the sensitivity of liver cancer detection by simultaneously detecting α-fetoprotein and glypican-3. To date, the most sensitive marker for pancreatic cancer has been identified as CA19-9, a mucin-glycoprotein tumor marker. Most patients with pancreatic cancer have a markedly elevated serum CA19-9 level. An anti-CA19-9 antibody was anchored on the membrane's surface to create a biosensor after the carboxylic group on the CNT was activated using NHS-EDC. By using impedance spectroscopy, the detection limit of CA19-9 in buffer solution was 0.35 U/mL. In the meantime, tests were conducted on samples that contained p53 antigen, ascorbic acid, and glucose to verify the biosensor's selectivity for the CA19-9 biomarker.

Cancer staging cannot be precisely detected or visualized by the CT and MRI imaging technologies available today. Active targeted imaging, which combines nanotechnology with endoscopic ultrasound (EUS), computed tomography (CT), and magnetic resonance imaging (MRI), can enhance tumor monitoring and make early screening more feasible. Using the solvent diffusion method, prepare NPs with diethylenetriamine pentaacetic acid (DTPA). Then, create PLA-PEG-PLL-Gd NPs by chelating the Gadolinium (Gd) ion with the DTPA group on the NPs' surface. A vascular endothelial growth factor (VEGF) antibody was added to the PLA-PEG-PLL-Gd NP to create a new multifunctional polymer nano contrast agent (anti-VEGF PLA-PEG-PLL-Gd NPs), which have an average size of 69.8 ± 5.3 nm. The uptake of VEGF PLA-PEG-PLL-Gd NPs in cells was higher than that of the non-VEGF-modified nanoparticles. Both in vitro and in vivo MRI demonstrated that the contrast agent could greatly increase the imaging signal and the chelating unit's relaxation. Since the imaging time was significantly increased from less than an hour to twelve hours, it appears that using anti-VEGF PLA-PEG-PLL-Gd NPs as a nano contrast agent has a lot of potential for the early detection of liver cancers. By coupling the uPAR targeted peptide U11, gadolinium diethylenetriamine penta acetic acid (Gd DTPA), and cyanine dye cy5, it created a targeted uPAR nanoprobe DGLU11 using endrograft poly-L-lysine (DGL) as a platform. Precancerous pancreatic intraepithelial neoplasia (PanIN) and pancreatic ductal adenocarcinoma (PDAC) lesions were imaged using dual-mode MR/near-infrared fluorescence (NIRF)-targeted molecular imaging. According to the findings, the targeted probe was more sensitive when it came to MRI fluorescence imaging. Magnetic resonance biomimetic/fluorescence imaging of gastric cancer can be successfully performed with Gd-dopping CuS NPs in conjunction with tumor targeting and MMP-2. The study showed that T-MAN nanoprobes can detect the metastases of gastric and lymph node cancer in mice.

The ability of nanotechnology to solve the problems of drug delivery and in vivo toxicity is one of its biggest benefits in the treatment of cancer. Drugs that are unstable or insoluble can be delivered via nanotechnology, which also increases the drugs' bioavailability and effectiveness.

1.1. Nanoparticle (Nanomaterials) Classification:

1.1.1. Nano Tube

These are cylindrical carbon molecules with unique characteristics that could be applied to a wide range of fields in the material sciences, electronics, and nanotechnology. Because the chemical bonding is consistent with sp2 orbital hybridization, they have exceptional strength, distinct electrical characteristics, and good thermal energy conductivity. Fullerene, a carbon allotrope, is one example. According to reports, a research team at the University of Connecticut has developed a device that can identify oral cancer from samples using a sensor made of densely packed carbon nanotubes coated with gold nanoparticles[5]. Silicon nanowires and carbon nanotubes have been used to identify different volatile organic compounds in breath samples from patients with gastric and lung cancer. [6]

Nowadays, carbon nanotubes are used in many different industrial and consumer applications. These include battery components, polymer composites, and a highly absorbent black paint that improves the mechanical, thermal, and electrical properties of the bulk product. High-strength textiles, biosensors for agricultural and biomedical applications, field effect transistors for electronics, and many more applications are being developed. Because of their relatively large surface area, CNTs can interact with a wide variety of medical and diagnostic agents, including medications, genes, vaccines, antibodies, biosensors, etc. Drugs can be delivered directly into cells with the aid of this. Furthermore, carbon nanotubes (CNTs) have recently been used as reinforcements in scaffolds and implants due to their suitable response area, high elastic modulus, and load-transfer capability.[7]

1.1.2. Nano Crystal

Their electrical and thermodynamic properties depend on their size, and they are crystalline materials with at least one dimension smaller than 1µm. Elan Pharma International Limited, an Irish company that formulates drugs using nanoparticles, is an example of these crystals. In the 10 nm range, nanocrystals exhibit a loose microstructure with nanopores positioned in between the crystals and are good semi-conductors. Because silica molecules have been added, the pores' surfaces have been altered to allow them to adsorb protein. These hydroxyapatite nanoparticles can be used to treat bone defects. Expanding treatment will also benefit from an international co-funding agreement for nanodrug development. [8] .

1.1.2. Nanobots

Also known as nanorobotics, these nanometer (10−9 m) robots have been used in healthcare, pharmacokinetic monitoring of diabetes, early diagnosis, and targeted drug delivery for cancer treatment. For example, when used as toothpaste or mouthwash, nanobots dentrifices (dentifrobots) can cover all subgingival surfaces and convert any trapped organic matter into odorless, innocuous vapors. Using appropriately configured dentifrobots, pathogenic bacteria found in dental plaque are detected and eliminated. Indeed, it has been suggested that patients will receive injections of nanobots to carry out tasks at the cellular level. Two excellent examples of nanobots are biochips and nanobots.[9]

1.1.3. Nanowires

Nanowires (NW) are nanoscale channels made of silicon, metal oxides, or carbon nanotubes that permit the passage of electrical current at very low amplitudes. They are extremely sensitive to even the smallest change in electrical properties, such as when another molecule is bonded to them, due to their tiny size and minute diameter, which is typically 10 nm. It is possible to affix antibodies to the surface of nanowires and use them as detectors. This way, when the antibodies interact with the target biomolecules, they undergo a conformational change that the nanowire detects as an electrical signal. As a result, multiple nanowires with various antibodies attached can be used as disease and cancer detectors when combined into a single device. Examples include Silicon nanowire (SiNW) used in sensors as Field Effect Transistors [10]. According to reports, FET-SiNWs can monitor prostate cancer and predict the risk of biochemical relapse before the disease fully manifests. They can also detect a number of prostate cancer biomarkers, including PSA (Prostate-Specific Antigen), at a very minute level.[11] Additionally, as reported in the literature, ribonucleic acid (RNA) expression levels of CTAs (cancer-testis antigens) have been measured using nanowire technology (observed in the Counter Analysis System) as biomarkers for aggressive prostate cancer. Since the binding of this negatively charged polyanionic macromolecule to p-type NW surfaces increases conductance, silicon and zinc oxide nanowires have also been used to detect ssDNA. Mutations linked to different types of cancer have been found using these DNA biosensors. For instance, the BRAF mutation for breast cancer was found using a nanowire platform functionalized with ssDNA.[12]

1.1.5. Quantum Dots

These are fluorescent inorganic crystalline nanomaterials. Quantum dots emit fluorescent light when exposed to low energy light; the color (or frequency) of this light is dependent on the dot's size. When excited, these variously sized dots could be incorporated into a particular microbead to produce a unique color spectrum. High sensitivity and wide excitation spectra can be obtained with such basic excitation, which makes it beneficial for molecular diagnostics, image-guided surgery, and genotype determination. Diagnostics and treatment have been combined through the conjugation of quantum dots with other diagnostic methods. For example, quantum dots can be covalently linked to fluorescence microscopy to view cells in living animals; specific cancer antibodies covalently linked to quantum dots covered with a polyacrilate cap have been used to achieve immunofluorescent labeling of the breast cancer marker Her2, and quantum dots with detectable luminescence encapsulated in carbohydrates are helpful in cancer imaging.[13] .

2. Available Nanoparticle-Based Platforms Employed in Nano diagnostics

2.1. Nanotechnology Based Biochips; Nanofluidics Microarrays

A contemporary technology of the severals for nanodiagnostics, it is also known as "lab on a chip." It is a straightforward apparatus that combines numerous DNA analysis procedures and is typically constructed of silicon or glass. The gadget is specifically made to interact with cellular components in a highly specific manner.

Composition: Microfluidic channels that offer pathways for biomolecules to flow to individual sensors or biosensors are typically found in lab-on-a-chip devices. It is primarily made up of fluidic channels that are microfabricated for the analysis of DNA samples that are nanoliter in size, an electrophoretic chamber, fluorescence detectors, and heater sensors for temperature. In order to accomplish a complex laboratory function in biomedical applications, it is frequently used as a tool for the analysis of small and low concentration samples.

Possibilities and Capabilities: In most cases, the DNA samples that will be analyzed are entirely unknown. Biomolecules like DNA can be analyzed, measured, and mixed with their containing solutions using nanofluidics. The DNA can then be digested to form distinct products, which can then be separated (isolated) and detected. In order to obtain complex laboratory information for biomedical applications, it is frequently utilized for the analysis of small and low concentration samples[14]. For the past ten years, this new detection technique has propelled the global economy and continues to expand. Systems biology, customized medications, identifying disease-causing organisms, and creating new medications are all made possible by nanofluidic technology. [15] .

How it works: Using a pipette, a solution containing DNA is introduced onto one fluid entry port, and a solution containing a reagent is introduced onto the other. Both solutions are drawn into the device by capillary action, but are stopped by hydrophobic patches that are positioned just past the vent point in each injection channel. To measure the right amount of DNA or reagent, air pressure lines must be positioned throughout the apparatus. As long as the sample is fluid, the device can precisely separate cell contents and analyze any cell component present by using the change in current in the device as the DNA moves.[16]

2.1.1. Protein Nanobiochips

These rely on silica nanoparticles that bind proteins. Protein chips have a lot of potential, despite still being in the early stages of development. Protein nanochips are made of thin silica nanoparticles, which can be layered, and proteins that have been configured onto them.

Operation: A robot immobilizes an array of protein antibodies and enzymes on a glass slide. A sample of interest is used to probe the slide's surface, attaches to the appropriate antibody on the chips, and is then examined using an appropriate detection technique. Personalized medicine and molecular diagnostics have been made possible by nanotechnology-produced miniature micro arrays. Proteins on arrays that are being profiled will be used to differentiate between the proteins of normal cells and those of early-stage or metastatic cancer cells. [17] .

2.1.2. Microelectromechanical Systems (MEMS)

Although it is related to microfluidics, this nanodiagnostic tool doesn't require fluidy substrate or reagents as a base. MEMS are primarily utilized in modern medication delivery, but they are also used in diagnostics as "Smart" capsular pills that provide an image of the gastrointestinal tract lumen, enabling medical professionals to view the tract's structures and potentially diagnose bleeding, its location, and its cause.

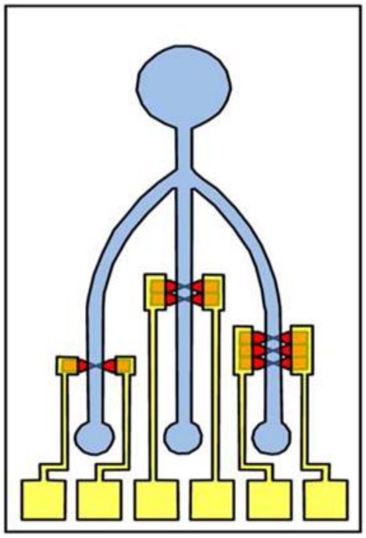

Figure 2. A lab-on-a-chip microfluidic device showing the inlet and outlets.

Capability: an image of the gastrointestinal lumen is captured and displayed as moving images using the capsular camera. Non-invasive techniques could provide a precise diagnosis of the internal structures' condition. Even at the stage of minute development, gastric ulcers and tumors could be readily observed at their precise locations.[18]

Workings: The patient must have swallowed the images captured by the capsular camera, which are transmitted to the patient via a belt that acts as a receiver. Images of the lumen captured by the "smart" capsule and sent to the worn belt receiver accompany the capsule's passage through the GIT. The expert can view the images by projecting them onto the screen. .The medical professional can draw conclusions for a potential diagnosis after observing this[19].

2.1.3. Nano Biosensors

Because nanomaterials are sensitive to both chemicals and biological changes, they can be used to identify specific cells or parts of the body, which makes them useful in medical diagnosis. These are composed primarily of a physical component (transducer for processing the sampling result) and a biological component (used for sampling).

In order to track the rate of growth and development of specific body regions and deliver targeted medications to them, nanobiosensors use indicators to identify and differentiate between cells, particularly cancer cells, by identifying the perculiar biomolecules that these cells release or produce. Even from outside the body, nanobiosensors could detect significant changes and signals that correspond to similar bodily products.[20]

Capabilities: By identifying the fluoresced nanodot that was previously injected, a doctor could locate tumors inside the body using the florescence properties of quantum dots of certain metals, such as cadmium selenide and zinc sulfide. Just identifying cells that differ from normal in morphology or biochemistry could lead to the early detection of cancerous tumors. Because it can detect specific DNA, genetic defects could be identified more precisely and earlier. According to published reports, scientists at Massachausset Institute of Technology (MIT) have figured out how to amplify weak biomarkers, which are peptides coated on nanoparticles that are released into the bloodstream by specific proteases that are frequently produced by cancer cells and then found in urine. [21]

2.1.4. Nanoscale Single-Cell Identification

This is another way that nanotechnology is being used. Cancer cells with characteristics that are similar to those of normal cells could be identified by using nanolaser scanning confocal spectroscopy, which has a high single cell resolution. Nanobiotechnology could be used to identify single-cell proteins. Biobarcode assays could detect even trace amounts of proteins in bodily fluids that are not detectable using traditional techniques.[22]

3. Future of Nanotechnology Application in Medical Diagnosis

There is increased hope for more possibilities due to the continuous giant strides in the field of nanodiagnostics. The development of devices that can be used for accurate molecular diagnosis at point-of-care (POC) has been spurred by these possibilities, which are caused by highly reduced-size particles, the high sensitivity of nanodiagnostics platforms, early detection of diseases and genetic dispositions at the molecular level using simple inexpensive rapid tests, and accurate imaging methods. The current diagnostic technologies work on the basis of finding disease-specific biomarkers. Handheld gadgets that are convenient and portable are popular. For example, the Gluco-watch, a wristwatch with nano-chip biosensors that aid in blood glucose monitoring. Some patients find these devices easy to use, which reduces hospital visits and eases the pressure on doctors to focus, leading to better practice. Nanodiagnostics facilitates medical practice. By using DNA sequence analysis for nanodiagnostic disease differentiation, doctors can proactively prevent potential disease presentations, unlike today when they must order medical tests to determine their educated guesses of a potential ailment. [23]

The potential for preventive medicine is greatly increased by the avalanche techniques in nanotechnology, which demonstrate how biological information can be obtained quickly, cheaply, and easily before being analyzed. As a result of these advancements in medical diagnosis, therapy is becoming more targeted and customized with favorable results. Because nanotechnology techniques and medications serve both therapeutic and diagnostic purposes simultaneously, therapy and diagnostics are actually rapidly merging into a new specialty medical field called theranostics. Examples include carrier systems that circulate preventively throughout the body in response to endogenous signals and automatically release active substances when necessary, and the contrast medium, which is composed of nanoparticles and brings the active substance directly with it in the event of a pathological tissue change. Research is also being done on the creation of nanomaterials that can identify damaged cells and their components, including individual genes, and fix them on their own within the organism.[24] .

Using nanoparticles, targeted transport of active ingredients can be utilized to deliver individual genes, DNA fragments, and nucleic acids into tissue and cells. Biodegradable, polymeric gene delivery nanoparticles have been demonstrated to efficiently kill brain glioma cells and prolong the animals' survival in a state-of-the-art animal study involving rats[25]. Further early diagnosis of illnesses with genetic predispositions is now feasible thanks to this discovery.

However, there are ethical questions raised by the endless potential of nanotechnology in diagnostic techniques. Among other things, who ought to have access to the records of a person's entire genetic sequence as determined by nanodiagnostics? Should all of a person's genetic information be in the hands of a medical professional or organization? What about concerns about medical information leaks as a potential consideration? What about instances where dishonest people have obtained such genetic data? Another area to consider is the use of MEMS devices inside the body. Computers could operate tiny devices called nanoassemblers to carry out specific tasks. The nanoassemblers might be able to fit into spaces that are difficult to access by hand or with other technology because they are smaller than a cell nucleus. used to eliminate oral bacteria that lead to dental caries or even fix areas of teeth where decay has occurred. These microscopic workers are guided In their work by a computer.

Before molecular nanotechnology can be considered as a potential solution to provide high-quality dental care to the 80% of the world's population that currently receives no significant dental care, social issues of public acceptance, ethics, regulation, and human safety must be addressed. Nanotechnology has enormous potential. The role of periodontitis will keep changing in accordance with the trends that are currently apparent. For instance, cases involving cosmetic procedures, acute trauma, or rare disease conditions will become relatively more commonplace, while simple self-care neglect will decrease.

The emphasis on particular diagnostic and therapeutic approaches may also shift in response to trends in oral health and disease. Cure prevention will become less necessary as preventive measures become more practical for the majority of them.

Each patient's genetics and preferences will be taken into account when making a diagnosis and treatment plan. There will be more exciting and varied treatment options available. All of this will require the highest technical proficiency and professional skills, which are the distinguishing characteristics of the modern dentist and periodontist, even more than they do now. Drugs could be administered more precisely with the use of nanometer and nanotube technologies. It should be possible for technology to target particular cells in patients with cancer or other serious illnesses. The toxic medications used to treat these diseases would become much more straightforward and, as a result, less damaging to the body. [26]

II. CONCLUSION

Nanotechnology and nanodiagnostics are more than just lab-based discoveries and consumer-use approvals from authorities and healthcare facilities. While closing the gap between developed and developing nations is essential, global coordination will be required for the establishment and upkeep of international standards and nomenclature, toxicity testing, risk assessment and mitigation, and public participation in order to achieve both benefits and safety. This will make it possible to use concrete, standardized characterization protocols that have been agreed upon globally for nanoscale products and items that can subsequently be used with biological systems. Monitoring for rigorous adherence to accepted, current, comprehensive, well-established guidelines and specifications will also be ensured by global coordination.

Using methods like molecular profiling, personalized medicine refers to a therapeutic approach that is customized to each patient's unique characteristics. We might be able to receive customized therapeutic treatments in the future thanks to nanotechnology. Multi-component systems known as theranostics, which can, for instance, combine therapeutic and diagnostic molecules, are examples of recently developed nanomedicines. The resulting nanosystem will enable drug delivery, diagnosis, and medication effect monitoring. The creation of such systems can aid in achieving the objective of obtaining customized treatments for a number of illnesses.

The fact that diseases like cancer are highly diverse and that current treatments only work for specific patients and at specific stages of the disease is the reason for the growing amount of research being done in the area of personalized nanomedicine. Since the imaging molecules allow for the real-time visualization of the drug's effect, administering a theranostic agent to a patient may allow for monitoring of how well the patient responds to the nanomedicine. Consequently, during follow-up, medication dosage and treatment regimens can be optimized and customized. Scientists are increasingly researching nanomedicines for a variety of medical uses. Personalized nanomedicine, in which a medication is given to a patient according to their genetic profile, and more effective drug delivery and targeting are two examples. Nanotechnology, and especially nanodiagnostics, has a bright future! The potential in this area of healthcare delivery will keep expanding with careful consideration of the related ethical issues and a global approach to the creation of international standards.

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