Nano Navigators: The Future of Dental Care with Nanorobotics

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Abstract. The technology of creating machines or robots at or close to the nanometer scale is called nanorobotics. It is the most modern application of nanotechnology. Using nanorobots in dentistry is predicted to improve precision, reproducibility, and dependability in the treatment process. These devices typically come in sizes ranging from 0.1 to 10 micrometer. With recent advancements in nanotechnology, it is now feasible to design such nanorobotic systems and create interfaces between them and the macro-world. Nano dentistry, with the incorporation of nanorobotics, nanomaterials, and biotechnology has the potential to achieve and maintain nearly perfect oral health. Although nanorobot research is still in its early stages, the potential for future applications is limitless!

Keywords: Nanorobot, Nanotechnology, Nanodiagnotics, Nanotreatment, Oral Cancer, Nanoanesthesia

1 Introduction

Nanorobotics is a subfield of nanotechnology that focuses on the design, development, and application of robots or devices with components at or near the nanometre (10-9 m) scale. [1]. Such nanostructured materials are designed to function as nanorobots capable of performing the targeted function at the nanometre or even cellular level. When directed by computer control systems they are capable of performing small and large scale tasks such as targeted drug delivery, medical diagnostics or surgical interventions either autonomously or together [1]. In the future, nanorobots must be designed so that they can

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handle the entire process from diagnosis of diseases all the way up to treatment and then to preventing disease [2]. Using molecular platforms and from an intimate knowledge of the molecular architecture of the human body, these machines seek to prevent diseases and promote overall human fitness. The novel properties at the nanometre scale have led to much attention from specialists in various fields such as medicine, dentistry, chemistry, physics, engineering, among others [3].

2 Mechanism of action

A variety of materials, such as carbon, nitrogen, hydrogen, sulphur, oxygen, silicon, and fluorine, are used to make nanorobots [5]. The most crucial element on the external surface of the nanorobot is carbon (C), which takes the shape of a diamond [6]. The residual elements are employed in a number of applications, including the manufacture of nanoscale gears and other components [7]. The body propels itself using oxygen, glucose, or other natural alternatives. Depending on the task at hand, they may include biological or molecular components [8].

- Nanorobots are metabolized by:
- Glucose
- Oxygen
- External acoustic energy

The rest of the internal power is used to deliver electricity to the devices [9]. The devices are programmed to perform over 1000 computations per second [6]. From record storage to pre-planned action, computers would keep track of everything [10]. Broadcast auditory signals are utilized in order to communicate with the device. Nanorobots of the navigational type can be inserted and their location recorded to provide a clear image [11]. It is easy to monitor all of the various sensors located throughout the body with this method. To achieve this, certain antigens on target cells are connected to chemotactic sensors. When nanorobots have finished their task, they can be removed by active scavenger systems or by going through regular human excretory pathways [11].

3 Application

Nanorobot is emerging as the future of dental care [12]. It has variety of applications like nano- diagnotics, nano- anesthesia, nano- solutions, nano- encapsulation, bone replacement materials, impression materials like nano- composites. It also plays a role in dental implant osseointegration and early detection of oral and pharyngeal cancer [13].

3.1 Nanodiagnotics

Nanorobots have a potential to aid in early disease detection at the cellular and molecular levels. It offers both in vitro and in vivo detection. They are utilized in vitro to collect and evaluate human subcellular fluids. Using in- vivo nanomedicine, we can create devices that work within the human body that aids in early detection of diseases, as well as quantifying toxic molecules and cancer cells [14].Oral cancer diagnosis and treatment: The saliva obtained from the human is a non-invasive and inexpensive medium used for analyzing and detection of oral cancer. It contains genomic and proteomic markers with 100 of nanometers types called as exosomes. The Exosomes contains the mRNA , which can be converted into proteins. These marker can be used for the diagnosis of malignancy. The commercially available ExoQuick TM used to probe the salivary exosomes. The oral cancer can be detected with the nanoelectromechanical system, optical nano bio-sensor test and oral fluid nano sensor test [15].

- Nano Electro Mechanical systems (NEMs): It is used for molecular detection of bacteria, virus, fungi and DNA so as to detect oral cancer and diabetes mellitus using the principle of transforming biochemical signal and cantilever array sensor to sensitive technology.
- Optical Nano Bio-sensors: Directed by the principles of optics and used for the generation of biochemical responses to appropriate output signals. The Fiber-optic probe enables non-destructive measurements of intracellular constituents, such as cytochrome C-essential for cellular energy metabolism and known protein associated with programmed cell death or apoptosis.
- Oral Fluid Nano-sensor Tests (OFNASET): It is a micro-electromechanical system with bio-detection micro-array (BMA) chip for electrochemical detection of cancer associated salivary proteins and RNA biomarkers [13]. The technique uses micro-fluid technology to effectively attach target RNA molecules or proteins to the sensor's surface. This is the process of automating analytical laboratory processes onto a single "chip" or gadget [12].The detection of oral, breast, pancreatic, and lung cancers, as well as type II diabetes, Alzheimer's disease, and Sjögren's syndrome, may be accomplished with high sensitivity and specificity using a panel of four salivary mRNA biomarkers (Oz/ten-m homolog-ODZ, IL-1b, IL-8, and SAT) and two salivary peoteomic biomarkers (IL-8 and thioredoxin).The applications of nanotechnology include:

- Photodynamic therapy (PDT);
- Stem cell therapy;
- Radiation immunotherapy based on nanotechnology;
- Ultrasound nanotheranostics; and
- Drug delivery systems in oral cancer treatment [16].

3.2 Nano- anesthesia

When nanorobots are used to induce anaesthesia, patient is injected with millions of active microscopic dental robots that can react to a suggestion made by the dentist. Although nanorobots can adhere to the tooth or its mucosal surface, they can also enter the pulp through the dentinal tubules, gingival sulcus, or lamina propria. Nanorobots can stop all nerve sensations by allowing nerve impulse traffic to be controlled in any nerve that requires special care. Upon treatment completion, patient will be anxiety free because of avoiding needle usage. It is rapid onset, short duration and has no residual effect [11].

3.3 Nano- solutions

These use special, dispersible nanoparticles as dentin bonding agents. They combine with solvents, polymers, and paints to create a homogenous mixture, which are also employed as solutions for sterilization. High bond strength, fluoride release, long shelf life, fluoride absorption, high stress absorption, and no need for acid etching are some of the benefits of nanoparticles [17].

3.4 Nano- composites and Nano- impression

There are two kinds of nanofillers used in composites: nano- meric and nano- cluster. Although the filler particle size cannot be whittled down below 100 nm, nanocomposite particles are sufficiently small to be created at the molecular level. High levels of filler loading, desirable handling qualities, and high polish retention are among its benefits; however, after curing, it may be more brittle and crack. They are incorporated into vinyl polysiloxanes to create a special siloxane impression material with improved precision, hydrophilic qualities, and flow [18].

Table 1. Applications of Nanorobots in Dentistry

Application	Main Use	Key Benefit
Nanodiagnostics	Disease & cancer detection	Early diagnosis
Nano-anesthesia	Nerve control	Needle-free treatment

Application	Main Use	Key Benefit
Nano-solutions	Bonding & sterilization	Strong adhesion
Nano-composites	Restorations & impressions	High precision
Oral hygiene	Bacteria removal	Halitosis control
Bone replacement	Bone regeneration	Faster healing
Dental implants	Osseointegration	Improved stability
Nano-prevention	Caries prevention	Enamel protection

3.5 Halitosis and oral hygiene

By identifying and eliminating bacteria found in plaque *and other places, the denti-frobots enable the harmless oral* microflora to thrive in a balanced environment. Since, the primary metabolic process causing oral malodor is bacterial putrefaction, they offer a constant defense against halitosis. Table 1 shows the application of nanorobots in dentistry.

3.6 Bone replacement material

Collagen is the main organic component of bone, which is reinforced by inorganic materials. Nanotechnology creates nanobones by replicating this natural structure. Nanocrystals have a loose microstructure because of the nanopores that are placed between the crystals. The pore surfaces are changed by the addition of silica molecules, enabling protein adsorption. These hydroxyapatite nanoparticles can be used to correct disorders of the bones. Examples are Vitosso (Orthovita, Inc.) HA + TCP (tricalcium phosphate), NanOSSTM HA (Angstrom Medica), and Ostim HA (Osartis GmbH, Germany).

3.7 Dental implants

The topography and surface contact area determine whether dental implants osseointegrate successfully. Nanotechnology can be used in implants to successfully promote bone development and improved predictability. Calcium phosphate and hydroxyapatite nanoscale deposits create a more complex implant surface for osteoblast formation. Because they enhance the tissues' capacity to incorporate nanocoatings that mimic organic components, these implants are more palatable [19].

3.8 Nano-Prevention

Fluorides, toothpastes, and fissure sealants contain nanoparticles that can help prevent dental cavities. Consequently, it is crucial for controlling enamel loss .

4 Biocompatibility and safety considerations

4.1 Biocompatibility

Introducing nanorobots into dental treatment presents numerous limitations and thus, requires careful consideration. The biocompatibility of nanorobots is a major concern, particularly when inorganic materials are used in their design. Nanorobots should be biocompatible and must not trigger any inappropriate immunological responses, possibly compromising nanorobot performance and risking patient safety [16]. To achieve seamless integration with the human body and to reduce the risk of toxicity or allergic responses, nanorobot materials must be thoroughly examined, tested, and optimized. Biocompatibility can be increased in nanorobots by using biocompatible polymers or surface modifications like PEGylation.

4.2 Safety Considerations

While expanding the use of nanorobots in a clinical setting, specific safety protocols must also be developed. It includes guidelines for sterilization, management, and disposal, as well as processes for addressing potential issues. The current state of nanotechnology necessitates the creation of more equitable ethical approaches as nanomaterials have the potential to harm human health and the environment. However, because the long-term impacts of nanotechnology are unknown, these potential risks may only become apparent after many years. There is a chance that the nanomaterials could occasionally enter the body through the lungs or skin and make their way to vital organs, which would be concerning. Furthermore, a nanoparticle's toxicity cannot be predicted only by its chemical constituents. Therefore, greater research on the potential risks of nanomaterials and nanorobots is necessary, and precautions need to be taken [13]. Fig 1. Shows the Biocompatibility and Safety Considerations of Dental Nanorobots.

Fig. 1. Biocompatibility and Safety Considerations of Dental Nanorobots

5 Results

5.1 Individual Design Accuracy Improvement

The introduction of smart computing systems made the design of removable partial dentures (RPDs) much more precise. The AI models were very sensitive in identifying undercuts, edentulous areas, abutment features, and design limitations. Experiments that simulated CNN-based and YOLOv8 architectures revealed that AI-aided learners had an equivalent level of accuracy as well-trained clinicians. Quantitative analysis showed that the design errors were also reduced by about 25 to 35% as compared to the traditional manual methods.

5.2 Minimization of Design Time and Workflow Productivity

Participants with AI-assisted systems took much less time to complete the tasks of RPD design. The average time of performing tasks was reduced by 20-40 %, especially surveying, undercut detection, and planning the framework stages. Simulation systems like RTS were interactive and could manipulate digital casts quickly and automatically validated the design.

5.3 Improvement in Student and Clinician Performance

Training platforms based on AI showed a great improvement in theoretical knowledge and skills. Students who were trained using simulation modules scored better in examinations and had better spatial reasoning and compliance with design principles. The performance tests showed a positive change in the scores on the test by 15-25 and an increased consistency in clinical decision-making.

5.4 Stability and minimization of fluctuation

The inter-observer variability was minimized by AI systems during the interpretation of the RPD design and planning. Intelligent tools generated designs that were more uniform as compared to those designs that were created manually. The longitudinal analysis implied continuous enhancement of design competency in learners who employed AI-based simulation tools. Even during long intervals of time, performance improvements were established. Fig.2 shows the Impact of intelligent computing on RPD

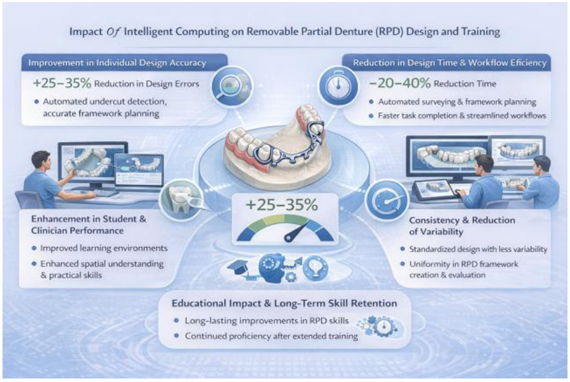

Fig. 2. Impact of intelligent computing on RPD

6 Future aspects

In the future, nanorobots are anticipated to be crucial to healthcare as it makes dentistry more reliable, accurate, and reproducible. It has the ability to significantly increase one's healthy life span. Nanorobots are effective at destroying infected cells, hence improving diseases. It will also help create ways to diagnosis, prevention, and treatment planning. Life will become simpler and easier with the discovery of nanorobots. Drug delivery technology will improve in precision and control. Gene treatment might also be possible. Nanorobots will be beneficial will benefit dentistry in the future. While nanorobots have enormous potential in dentistry, we must overcome several limitations before they can be widely used clinically.

7 Conclusion

Nanoworld is developing constantly and has the potential to completely transform dentistry. Researchers and experts are attempting to develop the most minute alterations using nanotechnology that will result in breakthrough diagnostic and treatment approaches for patients. Dr. Gregory Fahy defined nanorobots as "living organisms, naturally existing, fabulously complex systems of molecular nanotechnology". Nanorobotics is a fast expanding discipline that has the potential to transform dentistry in many ways due to their practically endless applications. It has made dental surgeons' jobs less stressful. It is one of the most efficient methods for preserving oral health. It uses mechanical dentifrobots, comprehensive orthodontic realignment, and hypersensitivity treatment, among other procedures, to maintain dental health. In order to preserve dental health, it employs mechanical dentifrobots, comprehensive orthodontic realignment, and hypersensitivity treatment, among other procedures. Nanorobots have the potential to improve medicine delivery, allow for more accurate surgical interventions, and even induce desirable cellular activity. Advancements in nanotechnology and robotics are paving the way for prospective dental treatments, despite hurdles including biocompatibility, high costs, and independent functionality. Future research should focus on improving nanorobots' biocompatibility, cost-effectiveness, autonomy, and the development of safe and efficient propulsion systems. In conclusion, nanorobots are tiny machines that have a big impact on dentistry. However, to overcome the difficulties of transferring nanorobotic research from the laboratory to the clinical setting, coordinated efforts are required. With upcoming technological advancements, we can expect nanorobots to become a standard feature in dentistry, improving patient outcomes and quality of life.Thus, nanorobots are not just shaping the future of dental care but are redefining it one molecule at a time.

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