

## **FUTURE IMPACT OF NANOTECHNOLOGY IN DENTISTRY – A REVIEW**

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### **ABSTRACT**

"Nanomedicine" is growing field which will revolutionize how dentists and physicians diagnose and treat disease and injury. "Nanotechnology" in the broader and more inclusive definition is referred as "molecular nanotechnology" or "molecular manufacturing". In the world of nanoscience, man goes more nearer to the creator in his understanding of nature. Twenty first century belongs to gene technology and nanotechnology. Nanotechnology is likely to touch every aspect of our life in the next few years.

**KEYWORDS:** Nanotechnology, Nano Dentistry, Nano Medicine

### **INTRODUCTION**

Nanotechnology is the science of manipulating matter measured in the billionths of meters or nanometer, roughly the size of 2 or 3 atoms. "Nano" is derived from the Greek word for dwarf. Nanotechnology will eventually offer humans means to manipulate matter atom by atom. A typical nanoassembler will be 8 times smaller than the nucleus of a cell.

### **PRACTICAL APPLICATIONS [1,2]**

#### **Monitoring Patients**

Most animal cells are 10,000-20,000 nm in diameter. This means that nanoscale devices [less than 100nm] can enter cells and interact with DNA and proteins.

To detect cancer at its earliest stages, scientists must be able to detect molecular changes even when they occur in a small percentage of cells. The potential for nanostructures to enter and analyze single cells suggests that they could meet this need.

#### **Electronics**

Using nanotechnology, electronic component size would shrink along with cost. It means complex appliances like computer, cell phone etc will be like throw away items.

#### **Automobile**

Changes in electronics and other field due to nanotechnology would possibly make automobile run on fuel assembled from nanotechnology.

#### **Possible Use of Nanostructure**

Improved methods of reading genetic code will help researchers detect errors in genes that may contribute to cancer.

### **Nanopores [3]**

Nanopores are tiny holes that allow DNA to pass through, one strand at a time and will make DNA sequencing more efficient. The pores are so small that DNA separation is being attempted using this structure. As DNA passes through a nanopore, scientists can monitor the shape and electrical properties of each base, or letter on the strand.

Since these properties are unique for each of the four bases that make up the genetic code, scientists can use the passage of DNA through a nanopore to decipher the encoded information, including errors in the code known to be associated with cancer.

### **Nanotubes**

Nanotubes are most common structures made of carbon atoms bonded into honeycomb-like shapes with enormous strength and electrical conductivity. These are carbon rods about half the diameter of a molecule of DNA that not only can detect the presence of altered genes, but may help researchers pinpoint the exact location of those changes. It helps to identify DNA changes associated with cancer.

### **Quantum Dots**

These are minuscule molecules making up tiny crystals that glow when stimulated by UV light. They are used to detect cancer. The wavelength or color of the light depends on the size of the crystal. Latex beads filled with these crystals can be designed to bind to specific DNA sequences. By combining different sized quantum dots within a single bead, scientists can create probes that release distinct colors and intensities of light. When the crystals are stimulated by UV light, each bead emits light that serves as a sort of spectral bar code, identifying a particular region of DNA. To detect cancer, scientists can design quantum dots that bind to sequences of DNA that are associated with the disease. When the quantum dots are stimulated with light, they emit their unique bar codes, or labels, making the critical, cancer associated DNA sequences visible [2,3,4]

They can be used in the body, eliminating the need for biopsy. They can be used to screen a blood sample for the presence of different viruses at the same time and to detect a set of proteins that indicates the patient is having heart attack. Quantum dots are similar to another technology called PEBBLES-Probes Encapsulated by Biologically Localized Embedding. PEBBLES were pioneered by Raoul Kopelman. It allows dye-tagged nanoparticles to be inserted into living cells to monitor metabolism or disease.

### **Nanoshells**

Nanoshells are minuscule beads coated with gold. By manipulating the thickness of layers making up the nanoshells, scientists can design these beads to absorb specific wavelengths of light. The most useful nanoshells are those that absorb near-infrared light, which can easily penetrate several centimeters of human tissue. The absorption of light by the nanoshells creates an intense heat that is lethal to cells. Researchers can already link nanoshells to antibodies that recognize cancer cells. Scientists envision letting these nanoshells seek out their cancerous targets, then applying near-infrared light. In laboratory cultures, the heat generated by the light-absorbing nanoshells has successfully killed tumor cells while leaving neighboring cells intact. [4,5,6]

### **Dendrimers**

Dendrimers are man-made molecules about the size of an average protein, and have a branching shape. This shape gives them vast amounts of surface area to which scientists can attach therapeutic agents or other biologically active

molecules. Dendrimers form nanometer by nanometer, so the number of synthetic steps or generations dictates the exact size of particles in a batch. The peripheral layer can be made to form a dense field of molecular groups that serve as hooks for attaching other useful molecules, such as DNA.

In 1998, James R. Baker pursued his work to use dendrimers as a safer and more effective genetic therapy agent. According to him, these nanostructures can sneak DNA into cells while avoiding triggering an immune response.

Upon entering a living cell, dendrimers of a certain size trigger a process called endocytosis in which the cell's outer membrane deforms into a tiny bubble or vesicle. The vesicle encloses the dendrimer which is admitted into the cell's interior. Once inside, DNA is released and migrates to the nucleus where it becomes part of cell's genome. It has been used in mammalian cell types and to be used in humans. Donald et al reported using glycodendrimer "nanodecoys" to trap and deactivate influenza virus particles. [5,6]

### **Nanobelt**

They have advantages over tubes in terms of price, flexibility and practicality. For making nanobelts, oxide is evaporated for 2 hours. The oxide contained zinc, tin, cadmium, gallium or indium. Nanobelt is deposited as wool like product.

The little straps have a rectangular cross section, with a width of 30-300nm and a thickness of 10-15nm and each belt was a single crystal. Because the material is already an oxide, it does not undergo a chemical reaction and has a pure, flawless surface.

While nanotubes are a few millionths of a meter long, the belts are millimeters long. While nanotubes are made of pure carbon, belts have been made from five oxides.

### **NANODEVICES AS A LINK BETWEEN DETECTION, DIAGNOSIS AND TREATMENT [7,8]**

The goal is to create a single nanodevice that will do many things:

- Assist in imaging inside the body
- Recognize precancerous or cancerous cells
- Release a drug that targets only those cells and report back on the effectiveness of treatment

### **Sensors**

The electrical conductivity of zinc oxide, for example, changes drastically when a gas molecule attaches, so that zinc oxide is used to detect flammable gases. Tiny sensors could replace existing ones, and find new uses as well.

### **Smart Windows**

Tin oxide treated with fluoride is used for this purpose. These high-tech pieces of glass respond to temperature changes by restricting the flow of UV light.

### **Flat-Panel Displays**

Indium oxide doped with tin is transparent, but electrically conducting, making it a promising material for advanced displays.

### **Electronic and Optical-Electronic Devices**

The tested oxides are semiconductors and are the main members of the "smart and functional materials" family. Thus nanobelts could be used to make tiny devices for electronic or fiber-optic purpose.

## CHALLENGES FACED BY NANODENTISTRY

- Precise positioning and assembly of molecular scale parts
- Economical nanorobot mass production technique
- Biocompatibility
- Simultaneous coordination of activities of large numbers of independent micron-scale robots.
- Social issues of public acceptance, ethics, regulation and human safety

## NANOTECHNOLOGY IN PERIODONTICS [8,9]

When the first micron-size dental nanorobots can be constructed, perhaps 10-20 years from today, how might they be applied to dentistry? Freitas has described how medical nanorobots might utilize specific motility mechanisms to crawl or swim through human body tissues with navigational precision, acquire energy, sense and manipulate their surroundings, achieve safe cytopenetration (e.g., pass through plasma membranes such as the odontoblastic process without disrupting the cell), and employ any of a multitude of techniques to monitor, interrupt, or alter nerve impulse traffic in individual nerve cells, in real time. Functions may be controlled by an onboard nanocomputer executing programmed instructions in response to local sensor stimuli. Alternatively, the dentist may issue strategic instructions by transmitting his orders directly to in vivo nanorobots via acoustic signals (e.g. ultrasound) or by other means.

### Local Anesthesia

Colloidal suspension containing millions of active analgesic micron-size dental nanorobots will be instilled on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1-3 micron thick layer of loose tissue at the cemento-dentinal junction. Upon reaching the dentin, nanorobots enter 1-4 micron diameter dentinal tubule holes & proceed towards the pulp, guided by a combination of chemical gradients, temperature differentials, & positional navigation, all under onboard nanocomputer control.

Assuming a ~10 mm total path length from tooth surface to pulp, a very modest nanorobot travel speed of 100  $\mu$  /sec completes the journey into the pulp chamber in ~100 sec. The presence of natural cells that are constantly in motion around and inside the teeth – suggests that such journeys should be feasible.

Once installed in the pulp and having established control over nerve impulse traffic, the analgesic dental nanorobots may be commanded by the dentist to shut down all sensitivity in any particular tooth that may require treatment. When the dentist presses the icon for the desired tooth on the handheld controller display, the selected tooth immediately numbs. After the oral procedures are completed, the dentist orders the nanorobots (via the same acoustic data links) to restore all sensation, to relinquish control of nerve traffic, and to egress from the tooth by similar pathways used for ingress, followed by aspiration.

Nanorobotic analgesics offer greater patient comfort and reduced anxiety, no needles, greater selectivity and controllability of analgesic effect, fast and completely reversible switchable action, and avoidance of most side effects and complications.

### Natural Tooth Maintenance

The appearance & durability of tooth may be improved by replacing upper enamel layer with covalently bonded artificial materials such as sapphire or diamond, which have 20 – 100 times the hardness & strength of natural enamel. It can be made more # resistant possibly including embedded carbon nanotubes.

### NEW TREATMENT OPPORTUNITIES IN PERIODONTICS

- Tooth Repair
- Hypersensitivity Cure
- Nanorobotic Dentifrice (Dentifrobots)

#### Tooth Repair [6,7]

Major tooth repair may evolve through several stages of technological development,

- First using genetic engineering,
- Tissue engineering and
- Later growing whole new teeth invitro & installing them.

Ultimately, the nanorobotic manufacture and installation of a biologically autologous whole replacement tooth including both mineral and cellular components (e.g., complete dentition replacement therapy) should become feasible to undertake within the time and economic constraints of an ordinary office visit, using an affordable desktop manufacturing facility in the dentist's office.

#### Hypersensitivity Cure

Reconstructive dental nanorobots would selectively and precisely occlude selected tubules in minutes, using native biological materials, offering patients a quick and permanent cure.

#### Nanorobotic Dentifrice (Dentifrobots)

- Subocclusal-dwelling nanorobotic dentifrice delivered by mouthwash or toothpaste could patrol all supragingival and subgingival surfaces at least once a day, metabolizing trapped organic matter into harmless and odorless vapors and performing continuous calculus debridement.
- Invisibly small (1-10 micron) dentifrobots, 10<sup>3</sup> - 10<sup>5</sup> nanodevices / oral cavity and crawling at 1-10 microns/sec.
- Would be inexpensive purely mechanical devices safely deactivate themselves if swallowed and programmed with strict occlusal avoidance protocols. Diamondoid nanomachines can be crushed by dental grinding.
- Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the ~500 species of harmless oral microflora to flourish in a healthy ecosystem.
- Dentifrobots would also provide a continuous barrier to halitosis, since bacterial putrefaction is the central metabolic process involved in oral malodor.
- With this kind of daily dental care available from an early age, conventional tooth decay and gum disease will disappear into the annals of medical history.

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