A critical review of the implication of nanotechnology in modern dental practice

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ABSTRACT

Curiosity has its own reason for existing. For thousands of years, mankind has been harnessing its curiosity into inquiry and the process of scientific methodology. If we consider technology as an engine, then science is its fuel. Science of miniaturization (nanotechnology) is manipulating matter at nanometer level and the application of the same to medicine is called nanomedicine. Nanotechnology holds promise for advanced diagnostics, targeted drug delivery, and biosensors. When we gain access to hold the nanorobots, we will be able to treat very rapidly a number of diseases that are a continuous threat for mankind today. The present article aims to provide an early glimpse on the impact and future implication of nanotechnology in dentistry, especially in oral surgery and orthodontics.

Key words: Dental practice, nanomedicine, nanoparticles, nanotechnology

Introduction

Greatness does not come from size. Surprises come in small packages. “Nano” is derived from the Greek word which stands for “dwarf”. Nanotechnology is the science of manipulating matter, measured in the billionths of meters or manometer, roughly the size of two or three atoms.[1] Nanomaterials are those materials with components less than 100 nm in at least one dimension, including clusters of atoms, grains less than 100 nm in size, fibers that are less than 100 nm diameter, films less than 100 nm in thickness, nanoholes, and composites that are a combination of these [Figure 1]. Nanoparticles are being applied in various industries, including medicine, due to various properties such as increased resistance to wear and the killing of bacteria, but there are worries relating to the unknown consequences they cause to the environment and human health. Now medical science is undergoing yet another change in helping mankind to enter a new era, the era of nanomedicine. Research in modern dentistry has discovered uses of these nanoparticles for fillings and sealant, and could lead to the creation of artificial bone and teeth.

Two perspectives of approaching nanodentistry

- Building up particles by combining atomic elements, i.e., bottom up approach[6,7]
- Using equipment to create mechanical nanoscale objects, i.e., top down approach[8]

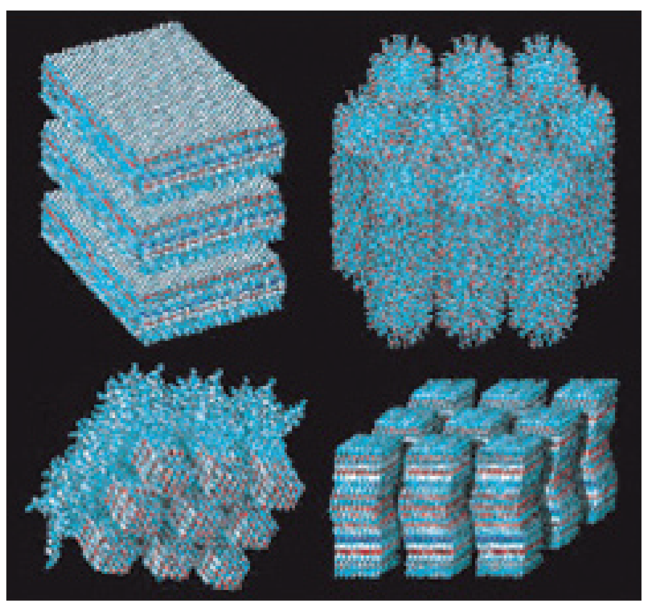

Figure 1: Nanoparticles in various shapes sheets, rods, grains, etc.

History

The term nanotechnology was coined by Prof. Kerie E. Drexler, a researcher and writer of nanotechnology.[2] Humans have been using nanotechnology for a long time without realizing it. The processes of making steel, vulcanizing rubber and sharpening a dental instrument all rely on manipulations of nanoparticles. Richard Zsigmondy studied nanomaterials in the early 20th century, and later discoveries culminated in ideas presented by Nobel Prize winning physicist Richard Feynman in a lecture called "Plenty of Room at the Bottom"[3] in 1959, in which he explored the implications of matter manipulation. Applications began in the 1980s with the invention of the scanning tunneling microscope[4] and the discovery of carbon nanotubes and fullerenes.

Application of nanotechnology in dentistry

Nanorobots might use specific motility mechanisms to travel through human tissues with navigational precision. They will acquire energy and sense and manipulate their surroundings. These nanorobotic functions may be controlled by an onboard nanocomputer that executes pre-programmed instructions in response to local nanorobots via acoustic signals or other means [Figure 2]. Various possible uses in dentistry are as follows

Local anesthesia

In the era of nanodentistry, a colloidal suspension containing millions of active analgesic micron-size dental robots will be instilled on the patient's gingiva. After contacting the surface of crown or mucosa, the ambulating nanorobots reach the pulp via the gingival sulcus, lamina propria and dentinal tubules, guided by chemical gradient, temperature differentials, all under the control of dentist with the help of onboard nanocomputer.[5] Once instilled in the pulp, the analgesic dental robots may be commanded by the dentist to shut down all the sensitivity in any particular tooth that requires the treatment. After oral procedures are completed, the dentist orders the nanorobots on the computer screen to restore all sensation, to relinquish control of nerve traffic and to egress from the tooth by similar pathways used for ingress.

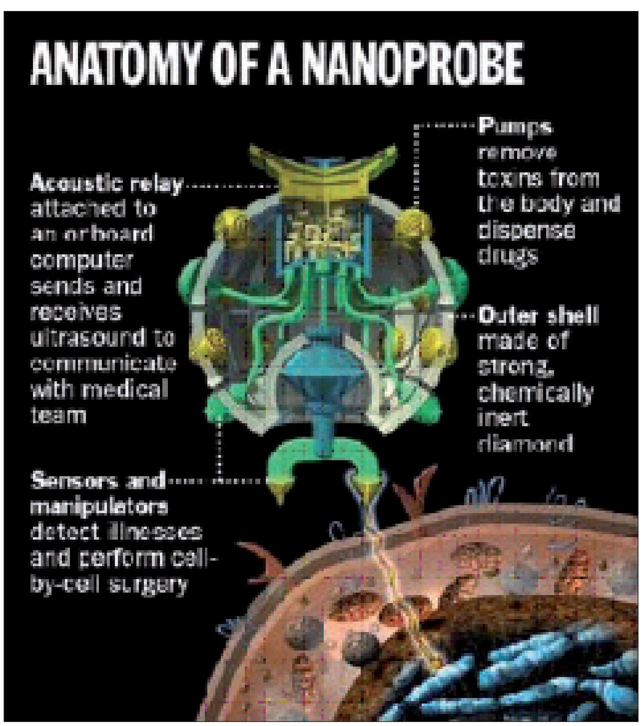

Figure 2: Autologous replacement of tooth by orthodontic nanorobots

Diagnosis and treatment of oral cancer

Nano electromechanical system (NEMS) converts biochemical to electrical signal and cantilever array sensor is an ultrasensitive mass detection technology that can be used for the detection of 10–12 bacteria, viruses and DNA. These are extremely useful in the diagnosis of oral cancer and diabetes mellitus and for the detection of bacteria, fungi and viruses. *Nanomaterials for brachytherapy* like "BrachySilTM" (Sivida, Boston & Perth, Australia) deliver 32P, are in the clinical trial. *Drug delivery system* that can cross the blood brain barrier is vision of the future with this technology. Parkinson disease, Alzheimer disease, brain tumors will be managed more efficiently. *Nanovectors for gene therapy* are in a developing stage to correct disease at molecular aspect.

Targeted cellular destruction

Quantum dots can be used as photo-sensitizers which can mediate targeted cellular destruction. They can bind to antibody present on surface of target cell and when stimulated by UV light, will release reactive oxygen species and this will be lethal to target cell. This therapy can be used to fight with malignant cells [Figure 3].

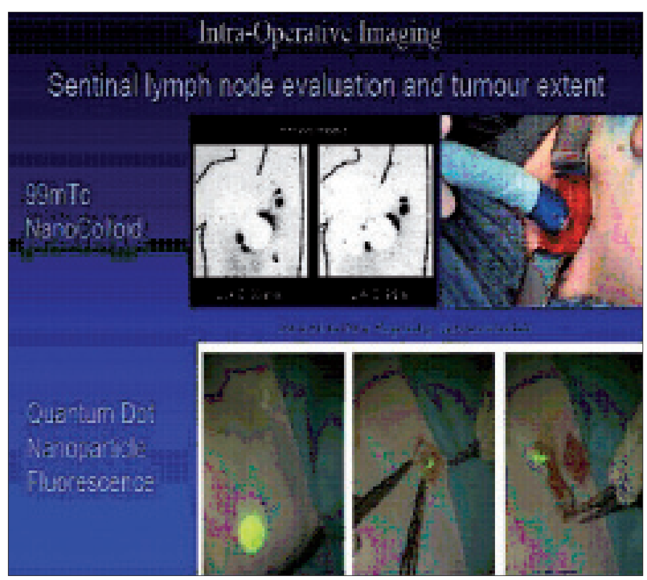

Figure 3: Intraoperative imaging malignant lesion by fluorescence nanoparticles and targeted malignant cell destruction by quantum dot nanoparticles

Bone replacement materials

Hydroxyapatite nanoparticles used to treat bone defects are

- Ostim® (Osartis GmbH& Co. KG, Obernburg-Germany) HA
- VITOSSO (Orthovita, Inc., Great Valley Parkway Malvern, PA 19355 USA) HA + TCP
- NanOSS™ (Angstrom Medica, USA) HA

These can be used in maxillofacial injuries requiring bone graft, cleft patient and osseous defect in periodontal surgeries.

Orthodontic treatment

Sliding a tooth along an archwire involves a frictional type of force that resists this movement. Use of excessive orthodontic force might cause loss of anchorage and root resorption. In a study published by Katz,[9] a reduction in friction has been reported by coating the orthodontic wire with inorganic fullerene-like tungsten disulfide nanoparticles (IF-WS_2), which are known for their excellent dry lubrication properties. In future, orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours.

Hypersensitivity cure

Dentin hypersensitivity may be caused by changes in pressure transmitted hydrodynamically to the pulp. This is based on the fact that hypersensitive teeth have eight times higher surface density of dentinal tubules and tubules with diameters twice as large as non-sensitive teeth. Dental nanorobots could selectively and precisely occlude selected tubules in minutes, using native biologic materials, offering patients a quick and permanent cure.

Nanoencapsulation

Nanomaterials, including hollow spheres, core-shell structure, nanotubes and nanocomposite, have been widely explored for controlled drug release. Pinon–Segundo *et al*.[10] studied Triclosan-loaded nanoparticles, 500 nm in size, used in an attempt to obtain a novel drug delivery system adequate for the treatment of periodontal disease. These particles were found to significantly reduce inflammation at the experimental sites. An example of the development of this technology is arestin in which minocycline is incorporated into microspheres for drug delivery by local means to a periodontal pocket.[11]

Tooth replacement

We are not far away when we will be able to generate whole new tooth with the principles of genetic engineering, tissue engineering and tissue regeneration, and manipulating cellular and mineral components at nanoscale. Chen *et al*.,[12] by using nanorods like calcium hydroxyapatite crystals which were oriented roughly parallel to each other, were able to simulate the natural biomineralization process and create hardest tissue in human body, i.e., dental enamel [Figure 4].

Impression materials

Nanofillers have been added to polyvinylsiloxane material to enhance its properties. Impression materials are available with nanotechnology application (Nano Tech Elite H–D+).These have better flow, fewer voids and enhanced detail precision.

Nanocomposite

Nanoscientists have successfully manufactured nonagglomerated discrete nanoparticles that are homogeneously distributed in resin or coating to produce nanocomposite (Feltech O Universal Restorative). These products have superior strength, hardness, esthetic appeal, excellent color density and high polish retention.

Challenges faced by nanodentistry

1. Engineering challenges
   - feasibility of mass production technique
   - precise positioning and assembly of molecular scale part
   - manipulating and coordinating activities of large numbers of independent microscale robots simultaneously
2. Biological challenges
   - developing biofriendly nanomaterial
   - ensuring compatibility with all intricate of human body
3. Social challenges
   - ethics
   - public acceptance
   - regulation and human safety

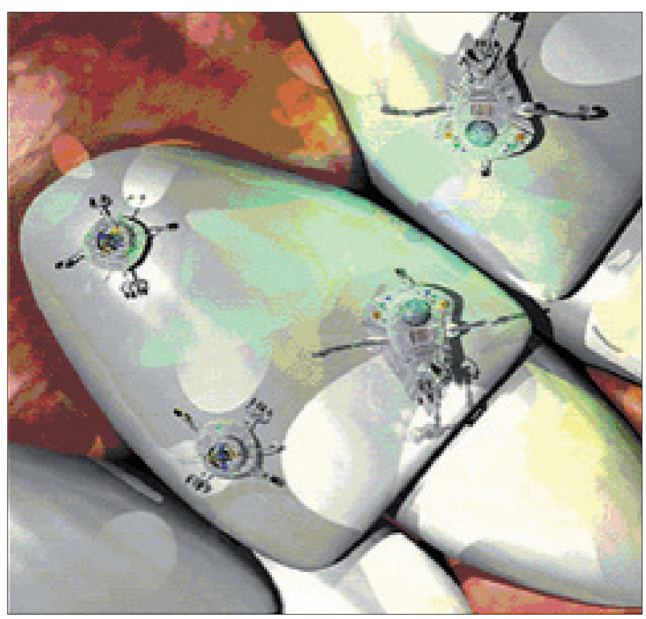

Figure 4: Control of nanorobots by onboard computer; sensor and manipulators detecting pathology and treating it

Nonetheless, there are equally powerful motivations to surmount these various challenges such as the vision that the 80% of the world's population that currently receives no significant dental care could enjoy a similar level of oral health to which citizens of the industrialized nations are already accustomed.

Role of dentist in practicing nanodentistry

The question arising in the mind is that if everything is done by computers then what will be the role of a dentist? But thankfully the role of dentist will evolve with time and it would be more exacting. Cases of simple neglect will become fewer and patients of rare disease and esthetic concern will become more. Treatment option will be more exacting and we will be able to make the diagnosis with patient preference and his genetic makeup in mind. All this will demand, even more so than today, the best technical abilities, professional judgment, and strong doctor–patient interpersonal skills that is the hallmark of the contemporary dentist.

Conclusion

It is hoped that we will be able to use nanotechnology to rebuild bone that has receded over time after a tooth has been extracted, making implants an option far longer than currently possible. A longer-term hope is that self-replicating nanomachines could repair and rebuild damaged teeth and oral tissue completely. As with all emerging technologies, a successful future for nanotechnology will only be achieved through open sharing of ideas and research finding, through testing and frank discussion.[13] In short, "Future is coming, it will be amazing." Time, advances, resources, and needs will determine which prospects becomes reality.

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