



REVIEW ARTICLE

Nanorobots: Future in dentistry

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Abstract The purpose of this paper is to review the phenomenon of nanotechnology as it might apply to dentistry as a new field called *nanodentistry*. Treatment possibilities might include the application of nanotechnology to local anesthesia, dentition renaturalization, the permanent cure for hypersensitivity, complete orthodontic realignment in a single visit, covalently bonded diamondized enamel, and continuous oral health maintenance using mechanical dentifrobots. Dental nanorobots could be constructed to destroy caries-causing bacteria or to repair tooth blemishes where decay has set in, by using a computer to direct these tiny workers in their tasks. Dental nanorobots might be programmed to use specific motility mechanisms to crawl or swim through human tissue with navigational precision, to acquire energy, to sense and manipulate their surroundings, to achieve safe cytopenetration, and to use any of a multitude of techniques to monitor, interrupt, or alter nerve-impulse traffic in individual nerve cells in real time.

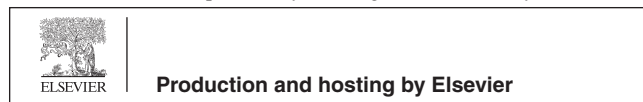
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1. Introduction

Researchers have predicted that high-tech and effective management at the microscopic level, termed nanotechnology, will become an important part of future dental and periodontal health. Nanotechnology, which is accomplished by manipulating matter at the atomic level, is measured in nanometers, roughly the size of two or three atoms. There is much controversy regarding the history of nanotechnology. Although some researchers believe that it is a scientific evolutionary form that did not develop until the late 1980s, evidence of nanotechnology dates back to 1959. Others believe that humans have unwittingly employed nanotechnological methods for thousands of years, perhaps even longer. However, nanotechnology is still fresh, providing a new arena for scientific research (Freitas, 2005).

One of the first mentions of the distinguishing concepts in nanotechnology (but predating the use of that name) was in 1867. At that time, James Clerk Maxwell proposed, as a thought experiment, a tiny entity known as Maxwell's Demon that was able to handle individual molecules. The first observations and size measurements of nanoparticles were made during the first decade of the 20th century by (Zsigmondy, 1914). Richard Feynman, at an American Physical Society meeting in 1959, was received with speculation when he gave a talk, "There's Plenty of Room at the Bottom". Four decades ago, the manipulation of single atoms and molecules seemed illusive; however, he predicted that the time would inevitably come when the atomically precise manipulation of matter would be possible.

The term "nanotechnology" was coined by a student at the Tokyo Science University in 1974 (Taniguchi, 1974). Nanotechnology consists mainly of the processing, separating, consolidating, and deforming of materials by one atom or molecule. Since its origin, the definition of nanotechnology has generally been extended to include features as large as 100 nm. *Nano* in Greek means "dwarf," which combines with a noun to form words such as *nanometer*, *nanotechnology*, and *nanorobot*.

Because of the growing interest in the future of dental applications of nanotechnology, a new field called *nanodentistry* is emerging. New treatment opportunities in dentistry include local anesthesia, dentition renaturalization, permanent cure of hypersensitivity, complete orthodontic realignment during a

single office visit, covalently bonded diamondized enamel, and continuous oral health maintenance with the help of mechanical dentifrobots that destroy caries-causing bacteria and even repair blemishes on the teeth where decay has set in (Rybachuk et al., 2009).

Dental nanorobots might use specific motility mechanisms to penetrate human tissue with navigational precision, acquire energy, and sense and manipulate their surroundings in real time. An onboard nanocomputer that executes preprogrammed instructions in response to local sensor stimuli could be utilized to control the nanorobot functions. Also, the dentist could issue strategic orders directly to the nanorobots *in vivo* via acoustic signals. Dental perspectives for nanorobots identified by previous researchers (Goene et al., 2007; Freitas, 1999) have included the combination of atomic elements to build nanoparticles and the creation of mechanical nanoscale objects.

2. Application of nanotechnology in diagnosis and treatment

2.1. Nanodiagnosics

Nanodiagnostic devices can be used for early disease identification at the cellular and molecular levels. Nanomedicine could increase the efficiency and reliability of *in vitro* diagnostics, through the use of selective nanodevices to collect human fluids or tissue samples and to make multiple analyses at the sub-cellular level. From an *in vivo* perspective, nanodevices might be inserted into the body to identify the early presence of a disease, or to identify and quantify toxic molecules, tumor cells, and so forth (Freitas, 2000; Lampton, 1995).

2.2. Diagnosis and treatment of oral cancer

Saliva is used as an inexpensive and noninvasively obtained diagnostic medium that contains proteomic and genomic markers for molecular disease identification. Exosome, a membrane-bound secretory vesicle, is one such marker whose level is elevated in malignancy. This marker has been studied by using atomic force microscopy, which employs nanoparticles. The nanoelectromechanical system, oral fluid nanosensor test, and optical nanobiosensor can also be used for diagnosing oral cancer.

Nanoshells, which are miniscule beads, are specific tools in cancer therapeutics. Nanoshells have an outer metallic layer

that selectively destroys cancer cells, while leaving normal cells intact. Brachytherapy is an advanced form of cancer treatment. Still under trial are nanoparticle-coated, radioactive sources placed close to or within the tumor to destroy it. Other uses of nanovectors include drug delivery across the blood–brain barrier in the treatment of Alzheimer’s and Parkinson’s diseases (Song et al., 2004; Wong, 2006).

3. Applications in clinical dentistry

3.1. Nanoanesthesia

When nanotechnology or nanorobots are used to induce anesthesia, the gingiva of the patient is instilled with a colloidal suspension containing millions of active, analgesic, micron-sized dental robots that respond to input supplied by the dentist. Nanorobots in contact with the surface of the crown or mucosa can reach the pulp via the gingival sulcus, lamina propria, or dentinal tubules. Once in the pulp, they shut down all sensations by establishing control over nerve-impulse traffic in any tooth that requires treatment. After completion of treatment, they restore this sensation, thereby providing the patient with anxiety-free and needleless comfort. The anesthesia is fast-acting and reversible, with no side effects or complications associated with its use (Freitas, 2000).

3.2. Nanosolutions

Because they produce unique and dispersible nanoparticles, nanosolutions can be used as bonding agents. Homogeneity is ensured, because the adhesive is mixed perfectly every time. Nanoparticles have also been used as sterilizing solutions in the form of nanosized emulsified oil droplets that bombard pathogens (Nagpal et al., 2011).

3.3. Impression materials

Nanofillers are integrated into vinylpolysiloxanes, producing a unique siloxane impression material that has a better flow, improved hydrophilic properties, and enhanced precision detail (Kumar and Vijayalakshmi, 2006).

3.4. Bone replacement materials

Bone is a natural nanostructure that is composed of organic compounds (mainly collagen) and reinforced with inorganic ones. Nanotechnology aims to emulate this natural structure for orthopedic and dental applications and, more particularly, for the development of nanobone. Nanocrystals show a loose microstructure, with nanopores situated between the crystals. The surfaces of the pores are modified such that they adsorb protein, due to the addition of silica molecules. Bone defects can be treated by using these hydroxyapatite nanoparticles (Kumar and Vijayalakshmi, 2006).

3.5. Nanoencapsulation

Targeted release systems that encompass nanocapsules are under trial for inclusion in vaccines and antibiotics (Kumar and Vijayalakshmi, 2006).

3.6. Dentine tubule blocking to alleviate hypersensitivity

Hypersensitivity is caused by changes in the pressure transmitted hydrodynamically to the pulp. The dentinal tubules of a hypertensive tooth have twice the diameter and eight times the surface density of those in nonsensitive teeth. These characteristics have led to the use of nanorobots that selectively and precisely occlude tubules in minutes, by using local, native materials, thus offering patients a quick and permanent cure (Nagpal et al., 2011).

3.7. Nanorobotic dentifrices (dentifrobots)

Nanorobotic dentifrices, when delivered either by mouthwash or tooth paste, can cover all subgingival surfaces, thereby metabolizing trapped organic matter into harmless and odorless vapors. Properly configured dentifrobots can identify and destroy pathogenic bacteria that exist in the plaque and elsewhere. These invisibly small dentifrobots are purely mechanical devices that safely deactivate themselves when swallowed.

3.8. Orthodontics

Orthodontic robots allow painless tooth uprighting, rotating, and vertical repositioning, as well as rapid tissue repair. A new stainless-steel wire that uses nanotechnology is being studied that combines ultra-high strength with good deformability, corrosion resistance, and surface finish.

3.9. Nanoneedles

Nanosized stainless-steel crystals incorporated into suture needles have been developed. Cell surgery may be possible in the near future with nanotweezers, which are now under development.

3.10. Nanocomposites

Microfillers in composites and microcore materials have long been in use. Although the filler particle size cannot be reduced below 100 nm, nanocomposite particles are minute enough to be synthesized at the molecular level. These nanoparticles improve the compressive strength of the material. Filler particles of submicron size, such as zirconium dioxide, are also necessary to improve polishability and esthetics. However, when particles of this size are used, the material may be more prone to brittleness and cracking or fracturing after curing.

To address this issue, hybrid composites and composites containing a wider distribution of filler particles have come into use. Although these composites display a better balance of strength and esthetics, they are weak due to nanoparticle clumping or agglomeration. This problem can be overcome by incorporating a proprietary coating process during the particle manufacturing procedure, thereby eliminating weak spots and providing consistent strength throughout the entire “fill” of the core build-up. Additionally, the even distribution of nanoparticles results in a smoother, creamier consistency and improves flow characteristics. Once the material is cured to its hardened state, these properties contribute to the dentin-like cutability and polishability of the material (Kumar and Vijayalakshmi, 2006; Abhilash, 2010).

3.11. Major tooth repair/nanotissue engineering

Replacement of the whole tooth, including the cellular and mineral components, is referred to as *complete dentition replacement*. This therapy is possible through a combination of nanotechnology, genetic engineering, and tissue engineering. Complete dentition replacement was the basis for research by Chan et al., who recreated dental enamel, the hardest tissue in the human body, by using highly organized microarchitectural units of nanorods.

3.12. Dental implants: structure, chemistry, and biocompatibility

The determining factors for successful osseointegration are surface contact area and surface topography. However, bone bonding and stability also play a role. Bone growth and increased predictability can be effectively expedited with implants by using nanotechnology. The addition of nanoscale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for osteoblast formation (Albrektsson et al., 2008; Goene et al., 2007). Extensive research on the effects and subsequent optimization of microtopography and surface chemistry has produced groundbreaking strides in material engineering. These new implants are more acceptable, because they enhance the integration of nanocoatings resembling biological materials to the tissues.

4. Conclusion

Nanotechnology in dentistry still faces many challenges. Conflicting views remain regarding the use of nanorobots *in vivo*. These views need to be addressed before nanotechnology can be incorporated into the armamentarium of modern medicine.

5. Conflict of interest

No conflict of interest is declared.

References

- Abhilash, M., 2010. Nanorobots. *Int. J. Pharma Bio. Sci.* 1 (1), 1–10.
- Albrektsson, T., Sennerby, L., Wennerberg, A., 2008. State of the art of oral implants. *Periodontology* 47, 15–26.
- Freitas, R.A., 1999. In: *Nanomedicine//Basic Capabilities*, vol. 1. Landes Bioscience, Georgetown, pp 345–347.
- Freitas, R.A., 2000. *Nanodent. J. Am. Dent. Assoc.* 131 (3), 1559–1566.
- Freitas Jr, R.A., 2005. What is nanomedicine? *Nanomed. Nanotech. Biol. Med.* 1, 2–9.
- Goene, R.J., Testori, T., Trisi, P., 2007. Influence of a nanometerscale surface enhancement on de novo bone formation on titanium implants: a histomorphometric study in human maxillae. *Int. J. Periodontics Restor. Dent.* 27, 211–219.
- Kumar, S.R., Vijayalakshmi, R., 2006. Nanotechnology in dentistry. *Indian J. Dent. Res.* 17, 62–69.
- Lampton, C., 1995. Nanotechnology promises to revolutionize the diagnosis and treatment of diseases. *Genet. Eng. News* 15, 23–25.
- Nagpal, Archana, Kaur, Jasjit, Sharma, Shuchita, Bansal, Aarti, Sachdev, Priyanka, 2011. Nanotechnology – the era of molecular dentistry. *Indian J. Dent. Sci.* 3 (5).
- Rybachuk, A.V., Chekman, I.S., Nebesna, T.Y., 2009. Nanotechnology and nanoparticles in dentistry. *J. Pharmacol. Pharm.* 1, 18–20.
- Song, J.M., Kasili, P.M., Griffin, G.D., Vo-Dinh, T., 2004. Detection of cytochrome C in a single cell using an optical nanobiosensor. *Anal. Chem.* 76 (9), 2591–2594.
- Norio, Taniguchi. 1974. On the Basic Concept of ‘Nano-Technology’. In: *Proc. Intl. Conf. Prod. Eng. Part II*, Tokyo, Japan Society of Precision Engineering, 18–23.
- Wong, D.T., 2006. Salivary diagnostics powered by nanotechnologies, proteomics and genomics. *J. Am. Dent. Assoc.* 137, 313–321.
- Zsigmondy, R., 1914. *Colloids and the Ultramicroscope*. Wiley, NY.