Nanodentistry : The Changing Trends in Dentistry

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Abstract

Nanodentistry is the future of dentistry in which every procedure will be performed using equipment and devices based on nanotechnology. There is increasing optimism that nanotechnology applied to medicine and dentistry will bring significant advances in the diagnosis, treatment, and prevention of disease. Growing interest in the future medical applications of nanotechnology is leading to the emergence of a new field called nanomedicine. Molecular technology is destined to become the core technology underlying all of 21st century medicine and dentistry. In this article, we have made an attempt to highlight in brief impact of nanotechnology in the field of dentistry.

Keywords : Nanotechnology, nanodentistry, nanorobots, dentrifrobots.

Introduction

The human characteristics of curiosity, wonder, and ingenuity are as old as mankind. People around the world have been harnessing their curiosity into inquiry and the process of scientific methodology. Recent years have witnessed an unprecedented growth in research in the area of nanoscience.[1] Science is undergoing yet another change, in helping mankind enter a new era, the era of nanotechnology. The word "Nano" is derived from the Greek word for 'dwarf.

According to Webpedia's Nanotechnology can be defined as "A field of science whose goal is to control individual atoms and molecules to create computer chips and other devices that are thousands of times smaller than current technologies permit." whereas Merrim Websters collegiate dictionary has defined nanotechnology as "The art of manipulating on an atomic or molecular scale especially to build microscopic devices/robots."

The growing interest in the future of medical applications of nanotechnology is leading to the emergence of a new field called Nanomedicine. "This is the science and technology of diagnosing, treating and preventing disease and traumatic injury by relieving pain, and preserving and improving human health, through the use of nanoscale structured materials, biotechnology and genetic engineering and eventually complex molecular machine system and Nanorobots (Fig 1)."[2]

Molecules and the Mouth

A research scientist Robert Freitas in the year 2000, was the first person to use the term Nanodentistry. He visioned nanotechnological developments that could enable dental consumers to achieve optimal oral health through the utilization of nanomaterials, tissue engineering and dental nanorobotics. Although the routine use of dental robots to identify and destroy pathogenic bacteria in the periodontal sulcus may be many years away, the use of nanotechnology in the area of dental materials is now becoming state of the art. Manipulating the structure of materials at the nano level (Fig 2) essentially has the capability of making significant improvements in its chemical, mechanical and optical properties.[3]

Nanodentistry

Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanomaterials, including tissue engineering, and use of dental nanorobots for dental treatments that may include local anaesthesia, dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondised enamel and continuous oral health maintenance using mechanical dentifrobots.

Nanomaterials in Dentistry

1. Dental Composites:[4,5,6,7] The chemical structure of dental composites has changed dramatically since the first composites were introduced in the 1960s. The first generation of composites contained large particles of quartz, glass and ceramic fillers. They had a rough surface when explored, and proved to be inappropriate for Class I and II restorations due to their low strength and high incidence of shrinkage. Microfilled composites developed in the 1970s had small particle size fillers to produce a lustrous surface, but they lacked strength due to expansion of the resin matrix. Hybrid composites came to the marketplace in the 1980s and featured a combination of large and small fillers thus providing increased strength and a smooth finish. The introduction of nonagglomerated discrete nanoparticles that are homogenously distributed in resins or coatings to produce nanocomposites by Nanoproducts Corporation has successfully enhanced esthetic features of high translucency and luster while maintaining strength and wear resistance (Fig 3). The nanofiller used include an aluminosilicate powder having a mean particle size of 80 ran and a 1:4 M ratio of alumina to silica and a refractive index of 1.508. They can now be placed in anterior as well as posterior teeth. The development of the nanofilled composite restorative materials provides clinicians and consumers with an esthetic and reliable tooth conserving option for replacing lost tooth structure.

Advantages

- Superior hardness;
- Superior flexural strength;
- Superior modulus of elasticity;
- Superior transluscency and esthetic appeal, excellent color density, high polish and polish retention;
- 50% reduction in filling shrinkage and excellent handling properties.

2. Bonding Agents:[4,5,6,7] Along with dental composites, bonding agents have also revolutionized modern dentistry. The ability to bond materials to both enamel and dentin began as a multi-step process requiring etching, rinsing, conditioning, priming and curing. The latest generation of bonding agents are self-etching, one-step materials. Nanosolutions (Fig 4) produce unique and dispersible nanoparticles, which can be used in bonding agents. This ensures homogeneity and ensures that the adhesive is perfectly mixed everytime.

Advantages

- Higher dentine bond strength and better performance.
- No shaking of bottle required since the nanoparticles are stable, neither do they

cluster nor do they settle out of dispersion.

3. Impression Materials : [4,5,6,7] Nanofillers have been integrated in vinylpolysiloxanes, producing a unique addition of siloxane impression materials. This development of automixed addition silicone impression materials has helped to eliminate many of the shortcomings of alginate and the old technology of reversible hydrocolloid impression materials.

Advantages

- Better flow,
- Improved hydrophilic properties hence fewer voids at margin and better model pouring,
- Enhanced detail precision.

4. Dental Implants :[4] Nanotechnology is now the latest technique being used in the fabrication of dental implants. While it has long been recognized that the microstructure of the titanium surface influences biocompatibility and osseointegration, the new nanotechnology-based dental implant surfaces represent a new generation of surface treatments. This addition of nano-scale deposits of hydroxyapatite and calcium phosphate creates a more complex implant surface for the osteoblasts to form on.

Advantage

This nanoengineered implant surface may play a key role in accelerating and enhancing the osseointegration process.

5. Nanoencapsulation: [4,6] SWRI [South West Research Institute] has developed targeted release systems that encompass nanocapsules including novel vaccines, antibiotics and drug delivery with reduced side effects.

6. Other products manufactured by SWRI[4] a. Protective clothing and filtration masks, using antipathogenic nanoemulsions and nanoparticles b. Medical appendages for instantaneous healing c. Bone targeting nanocarriers

7. Nanoneedles and Nanotweezers: [4] Suture needles incorporating nano-sized stainless steel crystals have been developed (Fig 5).

Nanotweezers are also under development which will make cell-surgery possible in the near future.

8. Bone replacement materials:[4] Hydroxyapatite nanoparticles used to treat bone defects are

- Ostim® (Osartis GmbH, Germany) HA
- VITOSSO (Orthovita, Inc, USA) HA +TCP
- NanOSS™ (Angstrom Medica, USA) HA.

9. Orthodontic wires:[7] Sandrik Nanoflex is a new stainless steel which allows ultra high strength combined with good formability, corrosion resistance and a good surface finish.

Applications of Nanorobotics To Dentistry

1. Major tooth repair:[2,7,8,9] Nanodental techniques for major tooth repair may evolve through several stages of technological development. First using genetic engineering followed by tissue engineering and tissue regeneration, and later involving the growth of whole new teeth in vitro and their installation. Ultimately, this nanorobotic manufacture and installation of a biologically autologous whole-replacement tooth that includes both mineral and cellular components that is, complete dentition replacement therapy should become feasible within the time (Fig 6).

2. Dentin hypersensitivity:[2,4,6,7,8,9] Dentin hypersensitivity is another pathological phenomenon caused by changes in pressure transmitted hydrodynamically to the pulp. Many therapeutic agents provide temporary relief for this common painful condition, but reconstructive dental nanorobots, using native biological materials, could selectively and precisely occlude specific tubules within minutes, offering patients a quick and permanent cure.

3. Tooth repositioning:[2,4,6,7,8,9] Orthodontic nanorobots could directly manipulate the periodontal tissues, including gingivae, periodontal ligament, cementum and alveolar bone, allowing rapid and painless tooth straightening, rotating and vertical repositioning within minutes to hours in contrast to current techniques, which require months to complete.

4. Durability and appearance:[2,4,6,9] Tooth durability and appearance may be improved by replacing upper enamel layers with covalently bonded artificial materials such as sapphire or diamond, which have 20 to 100 times the hardness and failure strength of natural enamel or contemporary ceramic veneers, as well as good biocompatibility. Pure sapphire and diamond are brittle and prone to fracture if sufficient shear forces are imposed, but they can be made more fracture-resistant as part of a nano-structured composite material that possibly includes embedded carbon nanotubes.

5. Nanorobotic Dentifrice (dentifrobots):[2,4,7] Effective prevention has reduced caries in children and a caries vaccine may soon be available, but 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. These invisibly small (1-10 micron) dentifrobots, perhaps numbering 10^3-10^5 nanodevices per oral cavity and crawling at 1-10 microns/sec, might have the mobility of tooth amoebas but would be inexpensive purely mechanical devices that would safely deactivate themselves if swallowed and would be programmed with strict occlusal avoidance protocols. 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 (Fig 7).

6. Inducing anesthesia:[4,6,7,8,9] Nanodentistry will have an effect on the way local anesthesia is induced in patients undergoing painful surgery or treatment. To induce oral anesthesia in the era of nanodentistry, micrometer sized particles will be used to reach down to the exact location of surgery where they will induce local anesthesia. A colloidal suspension containing millions of active analgesic micrometer-sized dental nanorobot "particles" will be instilled on the patient's gingivae. After contacting the surface of the crown or mucosa, the ambulating nanorobots will reach the dentin by migrating into the gingival sulcus and passing painlessly through the lamina propria or the 1- to 3-μmthick layer of loose tissue at the cemento-dentinal junction. On reaching the dentin, the nanorobots enter dentinal tubule holes that are 1 to 4 μm in diameter and proceed toward the pulp. All this will be controlled with the help of the nanocomputer operated by the dentist. The

advantages of inducing anaesthesia using nanorobots will include greater patient comfort, no anxiety, no needles, greater selectivity and controllability of analgesia, fast and completely reversible, no side effects and complications.

7. Photosensitizers and carriers:[4] Quantum dots can be used as photosensitizers and carriers. They can bind to the antibody present on the surface of the target cell and when stimulated by UV light, they can give rise to reactive oxygen species and thus will be lethal to the target cell.

8. Renaturalization procedures:[7,8,9] Dentition renaturalization procedures may become a popular addition to the typical dental practice, providing perfect treatment methods for esthetic dentistry. This trend may begin with patients who desire to have their old dental amalgams excavated and their teeth remanufactured with native biological materials. However, demand will grow for full coronal renaturalization procedures in which all fillings, crowns and other 20th-century modifications to the visible dentition are removed, with the affected teeth remanufactured to become indistinguishable from the original teeth.

How safe are these nanorobots?[4,6]

The nonpyrogenic nanorobots used in vivo are bulk Teflon, carbon powder and monocrystal sapphire. Pyrogenic nanorobots are alumina, silica and trace elements like copper and zinc. If inherent nanodevice surface pyrogenicity cannot be avoided, the pyrogenic pathway is controlled by in vivo medical nanorobot. Nanorobots may release inhibitors, anagonists or downregulators for the pyrogenic pathway in a targeted fashion to selectively absorb the endogenous pyrogens, chemically modify them, and then release them back into the body in a harmless inactivated form (Fig 8).

Challenges faced by nanodentistry[4]

Nanodentistry faces many significant challenges in bringing its promises to fruition. These include:

- Precise positioning and assembly of molecular scale part
- 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.

Future of Nanotechnology:[4] Nanotechnology is foreseen to change health care in a fundamental way:

- Novel methods for disease diagnosis and prevention
- Therapeutic selection tailored to the patient's profile
- Drug delivery and gene therapy.

Conclusion

The science of nanodentistry might sound like a fiction now, but it has strong potential to revolutionize dentist to diagnose and treat disease in future. It opens up new ways for vast, abundant research work. Nanotechnology will change dentistry, health care and human life more profoundly than other developments. However, some scientists believe that other than providing unlimited benefits, these devices can also bring dangers due to mishandling or misuse. But again everything has its pros and cons and if we look at nanodentistry we find that its pros far outweigh the cons and therefore we should be looking forward to its emergence and popularity. The promise of such technology is endless and one day would surely revolutionarize the medical and dental field.

References

1. Patil M, Mehta DS, Guvva S. Future impact of nanotechnology on medicine and dentistry. J Indian Soc Periodontol 2008;12:34-40.
2. Hiremath SS, Anegundi RT. Nanorobotics in Dentistry. August 2006;29. www.dharwadhubli.com.
3. Molecular momentum. http://www.dentalproductsreport.com/articles/show/mh0308_we_nanotechnology March 2008 | Modern Hygienist. Accessed 19,2011.
4. Kumar SR, Vijayalakshmi R. Nanotechnology in dentistry. Indian J Dent Res 2006;17:62
5. Jhaveri HM, Balaji PR. Nanotechnology: The future of dentistry. J Indian Prosthodont Soc 2005;5:15-7
6. Rybachuk AV, Chekman IS, Nebesna TY. Nanotechnology and Nanoparticles in Dentistry. National O.O. Bohomolets Medical University 2009;1:18-21.
7. Gorav S, Kamlesh V, Nidhi P. Nanodentistry The future ahead. BFUDJ July 2010;1(1):43-45.
8. Sujatha V, Suresh M, Mahalaxmi S. Nanorobotics A futuristic approach. SRM University Journal of Dental Sciences June2010;1(1):86-90.
9. Freitas RA Jr. Nanodentistry. J Am Dent Assoc 2000;131(11):1559-1565.

Legends

Fig 1: Dental Nanorobot
Fig 2: Nanoparticles at molecular level
Fig 3: LuxaCore Z-Dual (a dual-curing premium composite with zirconium dioxide and nano technology for core build-ups and root post cementations).
Fig 4: Nanosolutions
Fig 5: Nanoneedles
Fig 6: Cell repair Nanorobot
Fig 7: Nanorobots undergoing oral prophylaxis
Fig 8: Nanorobot

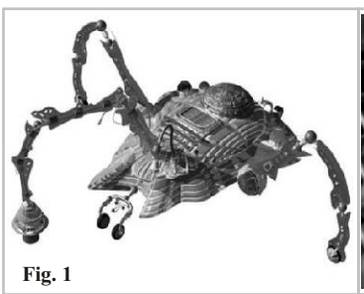
Fig. 1

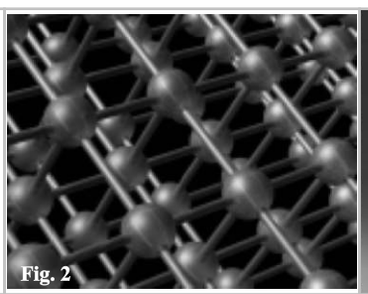
Fig. 2

Fig. 3


Fig. 4

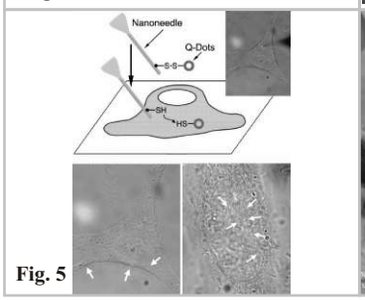

Fig. 5


Fig. 6


Fig. 7

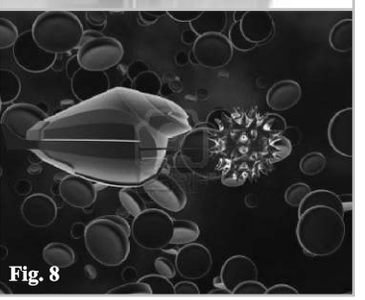
Fig. 8