Nanodentistry – The New Horizon

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Abstract

Developments in dentistry, driven by years of research, have made dental procedures less painful, fast, reliable, effective and safe. Innovative technologies such as digital dentistry, lasers, cosmetic dentistry, implants, nanotechnology, and nanorobots have had a significant impact on the dental equipment and efficiency of dental personnel. Nanotechnology in particular, has emerged as a promising area of interest in dentistry due to the variety of new treatment options it offers. Nanodentistry will make possible the maintenance of near-perfect oral health and oral health trends will change the focus on specific diagnostic and treatment modalities.

INTRODUCTION

Nanotechnology refers broadly to a field of applied science and technology whose unifying theme is the control of matter on the molecular level in scales smaller than 1µm, normally 1-100nm, and the fabrication of devices within that size range.[1] "Nano" is derived from the Greek word for "dwarf" and nanotechnology is the science of manipulating matter measured in the billionths of meters or nanometers, roughly the size of 2 or 3 atoms.[2] For perspective, the size of one hydrogen atom is 0.1 to 0.2nm and of a small bacterium about 1000nm.[3]

The vision of nanotechnology was introduced in 1959 by late Nobel Physicist Richard P Feynman who proposed employing machine tools to make smaller machine tools, which are to be used in turn to make still smaller machine tools, and so on all the way down to the atomic level.[4] In his historical lecture in 1959, he said "this is a development which I think cannot be avoided."[2]

Dentistry is facing a major revolution in the wake of nanotechnology, having already been targeted by novel "nanomaterials".[6] Nanodentistry will make possible the maintenance of comprehensive oral health by employing nanomaterials, biotechnology, including tissue engineering, and ultimately dental nanorobotics.[4]

Nanotechnology is still in the very early stages of research only becoming possible in the last century and is yet to be fully understood since many materials begin to act very differently on these nanoscales, often changing their properties in an unusual manner.[5]

NANOROBOTS

Nanorobots are robots at the nanoscale. Just as robots assemble cars in factories from a set of predefined parts, nanorobots will assemble things from atomic and molecular building blocks. Nanorobots exert precise control over matter. Currently, we can grow only certain almost-perfect crystals in very simple patterns. Nanorobots will allow us to construct such crystals, molecule by molecule, as incredibly fine-grained atomic structures, following a detailed blueprint. Assembling any object of tangible size this way may seem like a slow and tedious process. However, billions of nanodevices working together on the same object cut the required time by many orders of magnitude.[7]

APPLICATIONS IN DENTISTRY

When the first micrometer sized dental nanorobots are constructed, perhaps 10 to 20 years from today, their functions will be controlled by an onboard nanocomputer that will execute preprogrammed instructions in response to local nanorobots via acoustic signals.[8] These nanorobots will be able to bring about a variety of functions.

Inducing Anesthesia. A colloidal suspension containing millions of active analgesic micrometer-sized dental nanorobot "particles" will be instilled on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach the dentin and finally the pulp by migrating into the gingival sulcus and passing painlessly through the lamina propria and the

dentinal tubules.[8] Once installed in the pulp, the robots may be commanded by the dentist to shut down all sensitivity in any particular tooth that requires treatment.[2]

Hypersensitivity Cure. Hypersensitive teeth have 8 time 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, offering patients a quick and permanent cure.[2]

Oral Hygiene and Halitosis. Properly configured dentifrobots could identify and destroy pathogenic bacteria residing in the plaque and elsewhere, while allowing the 500 or so species of harmless oral microflora to flourish in a healthy ecosystem. Dentifrobots also would provide a continuous barrier to halitosis, since bacterial putrefaction is the central metabolic process involved in oral malodor.[8]

Periodontal Tissue Engineering. Tissue engineering concepts for periodontal regeneration are focused on the utilization of synthetic scaffolds for cell delivery purposes. Non-biologic self-assembling nanosystems will automatically undergo pre-specified assemblies much in line with known biologic systems associated with cells and tissues.[9]

Stronger Resin-Based Composite. The potential to produce restorations that are stronger than today's resin-based composite restorations and more effective in preventing secondary caries exists with nanotechnology. Nanoscale silica-fused fibers have also been produced that produce a resin-based composite nearly twice as strong as the currently available resin-based composite materials.[10]

Nanosolutions. Nanosolutions produce unique and dispersible nanoparticles, which can be added to various solvents, paints and polymers in which they are dispensed homogenously. This can be made use of dentin bonding agents (Adper™) as they have better dentin bond strength and better performance.[6]

Impression Materials. Impression materials are available with nanotechnology application. Nanofillers are integrated in the vinylpolysiloxanes, producing a unique addition siloxane impression material. These materials have better flow and enhanced detail precision.[6]

Healing of Wounds. Nucryst (Wakefield, USA) has made a wound-healing material (dressing) that is generally used in specialist burn-treatment hospitals in America. The dressing contains nanocrystalline silver that stops 150 types of fungus and bacteria, including several bacteria that are resistant to antibiotics. Meanwhile, another company has placed nanoparticles into a plastic material to make it biocidal. This can be useful for devices that are placed inside the body.[11]

Orthodontic Treatment. Orthodontic nanorobots could directly manipulate the periodontal tissues, allowing rapid and painless straightening, rotating, and vertical repositioning within minutes to hours.[2]

Bone Replacement Materials. Several bone graft materials are available today in the nanoparticle size. These show better properties than the conventional size graft materials. Nanoparticle bone grafts include – Ostim®, VITOSS®, NanOss™ and SynthoGraft®.[2]

Personalized Treatment. Dentists will perform routine examinations that will include use of high-resolution imaging devices to better visualize the subsurface tomography of each tooth. Advanced nanomaterials will exist that will deliver biologically based therapies to promote remineralization naturally. Dentists will possess additional predictive tools to characterize bacteria underlying infections and the specific nature of the immune response will be developed, and they will be able to personalize treatments using nanoparticle drug delivery systems, that most effectively target and eliminate both the bacteria and the infection.[1,12]

Major Tooth Repair. Nanodental techniques for major tooth repair may evolve through several stages of technological development, first using genetic engineering, tissue engineering and tissue regeneration, and later involving the growth of whole new teeth in vitro and their installation. "Complete dentition replacement therapy" should become feasible within the time and economic constraints of a typical office visit.[8]

Surgical Devices. A surgical knife from microstructured-silicon with a diamond-layered tip has been developed. Diamond is a material that is chemically rigid, and silicon is non-magnetic and biocompatible. The knife therefore makes sharper incisions and with a lower penetration pressure.[11]

Surgical Nanorobotics. A surgical nanorobot, programmed or guided by a dentist, could act as a semi-autonomous on-site surgeon inside the human body. Such a device could perform various functions such as searching for pathology and then diagnosing and correcting lesions by nanomanipulation, coordinated by an onboard computer while maintaining contact with the supervising surgeon via

coded ultra sound signals.[13]

LIMITS AND RISKS

The potential economic, medical, and environmental benefits may give the false impression that nanodentistry will create a wondrous utopia in which all dental problems are solved.[14] There are certain limits to what nanodentistry, and nanotechnology in general, can accomplish.

Knowledge. While products based on nanotechnology are actually reaching the market, sufficient knowledge on the associated risks is still lacking. Reducing the size of structures to nanolevel results in distinctly different physical properties and these have not been largely evaluated till date.[15]

Nanoparticle Toxicity. Toxicity of nanoparticles cannot be predicted from the toxicity known for the chemical entity itself. Size reduction to nanolevel is accompanied with a change in chemical reactivity and thus, presumably, toxicity.[15]

Molecular Assembly. Precise positioning and assembly of molecular scale parts in nanomachines and nanoproducts is a major technical issue over.[2]

Economics: Currently nanodentistry products are costly. However, this may not be a problem in the future, when nanoproducts will be manufactured on a mass scale.[2]

Information Loss. Variations in genetic code between individuals are important, both to the individuals themselves and to the health and prospects of the species as a whole. Much of the diversity of this genetic information has been lost over time, and it is irretrievable.[14]

PHYSICAL LIMITS

The limits of their technology are confused with the limits of the possible. The physical limits are real, and all technology, past, present, and future, will stay within those limits. Nanotechnology will make it possible to push closer to the real limits set by natural law, but it will not change those laws or the limits they set.[14]

Population. Natural law imposes limits, but so does the nature of human beings. These will continue as long as people do.[14]

THE FUTURE

Predicting the future is risky business.[12] However, it is not too early to consider, evaluate and attempt to shape potential effects of nanodentistry.[7] Nanotechnology will change dentistry, health care and human life more profoundly than many developments of the past.[11]

Nanodentistry will lead to efficient and highly effective personalized dental treatments. A new generation of cell-based therapies will be available for regenerating tissues, and anti-inflammatory drugs and pain medications will be tailored to maximize efficacy and safety.[12]

The miracles of nanodentistry envisioned by dentists might sound unlikely, implausible or even heretic.[4] Yet, the theoretical and applied research to turn them into reality is progressing rapidly. However, as with all technologies, nanotechnology carries a significant potential for misuse and abuse on a scale and scope never seen before. Nanodevices cannot be seen, yet carry powerful capabilities. They also have the potential to bring about significant benefits, such as improved health, better use of natural resources and reduced environmental pollution.[7] The future might truly bring the days of miracle and wonder.

CONCLUSION

The tools of modern science have surprised, intrigued and dazzled our imagination. They have improved the oral health of and quality of life for countless people and communities.[12] Nanomaterials and nanoparticles are likely to be cornerstones of innovative nanodental devices to be used for drug discovery and delivery, discovery of biomarkers, and molecular diagnostics.[1] New treatment opportunities may include dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondized enamel and continuous oral health maintenance through the use of mechanical dentifrobots.[8]

Nanotechnology seems to be where the world is headed if technology keeps advancing, and competition practically guarantees that advances will continue.[14] It will open a huge range of opportunities of benefit for both the dentist and the patient.

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