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THE POTENTIAL OF NANOTECHNOLOGY IN DENTISTRY

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Abstract:
The physical, chemical, and biological characteristics of structures and their constituent parts at the nanoscale are the focus of nanotechnology. The idea behind nanotechnology is to regulate individual atoms and molecules to create functioning structures. Numerous advancements in the fields of materials science, biotechnology, electronics and computer technology, aviation, space exploration, and health sciences will be made possible by the application of this technology. Nanotechnology is particularly expected to deliver breakthroughs in dentistry and novel approaches to oral health-related diagnostic and therapeutic procedures, in tandem with improvements in materials science and biotechnology. (2013) Eur J Dent 7:145–151

Key words: nanocomposite, nanotechnology, dentistry, and Nano dentistry.

Introduction:

Science is currently going through a significant evolution that is leading humanity into a new era: the era of nanotechnology.1 It is not often that one gets to see the start of a groundbreaking advancement in technology.
The initial inquiries concerning nanotechnology in dentistry pertain to its application and the duration needed to translate research findings into clinical practice. Literally meaning one billionth of a physical size, the word "nano" is a prefix derived from the Greek word (nannos), which means "dwarf." One nanometer (nm), a unit of length, equals 1 billionth of a meter.3 A single hair strand has a thickness of 100,000 nm, making it simpler to picture and comprehend the meaning of the term "nano."4 Atoms are roughly 0.1 nm in size. It is evident that the field of nanotechnology operates at the level of atoms and molecules given that a useful nanostructure can range in size from 1 to 100 nm.3
The direct manipulation of materials at the nanoscale is defined as nanotechnology by the National Nanotechnology Initiative.5 This phrase describes a technology that allows for nearly total control of the structure of matter at nanoscale scales. By arranging atoms in any way we choose, nanotechnology will enable us to effectively and totally control the structure of matter.6, 7

The objectives of nanotechnology are to create devices with nano-precision, construct nanoscale structures, comprehend the physical features of structures at the nanoscale dimension, analyze structures at the nanoscale, and create a connection between nanoscopic and macroscopic cosmos by developing suitable techniques.8 The foundation of nanotechnology is the idea of creating functional structures one atom at a time.1 The fact that nanoparticles are smaller than the critical lengths defining many physical events gives them unique properties and makes them interesting.9 Nanotechnology is generally translated as “the science of the small.”10 However, in addition to creating small structures, nanotechnology also entails inventing materials, devices, and systems with properties that differ from those of large-scale structures in terms of biology, chemistry, and physical attributes.

The process of developing nanotechnology

At the American Physical Society's annual meeting in 1959, nano-phase materials were first discussed in an academic setting. Physicist Richard P. Feynman (1918–1988), winner of the Nobel Prize in physics, spoke at this meeting under the title "There is plenty of room at the bottom." Feynman predicted that manufacturing at the scale of atoms and molecules would lead to many new inventions, but first specific techniques for measurement and manufacturing at the nanoscale should be developed to realize this possibility. Feynman's well-known speech is recognized as the founding moment of nanoscience and nanotechnology.11 Since then, both experimental and theoretical developments have advanced rapidly.

nanomedicine :

A new field called nanomedicine has emerged as a result of advances in the medical applications of nanotechnology.11 Initially proposed by Robert A. Freitas Jr. in 1993, nanomedicine is defined as the observation, manipulation, and treatment of the biological systems of the human body at the molecular level through the use of nano-structures and nano-devices.

Applications for nanomedicine range from tissue scaffolds based on nanotechnologic design that realizes tissue formation to drug release with nanospheres and even nanorobots for diagnostic and therapeutic purposes.13 Drug molecules carried by the circulatory system through the body may cause undesired adverse effects.

impacts in areas not intended. Conversely, sick cells can be identified by nanorobots, which can then identify and eliminate them wherever they may be. In the case of cancer, precise drug delivery to the target is crucial for eliminating all cancer cells while protecting healthy cells from damage.14

With the use of simple nanomaterials and nanodevices, some of which are currently able to be manufactured, nanomedicine can solve a number of significant medical issues. Given that the outcomes of several studies conducted in the field of nanomedicine today are almost ready to be put into reality, it can be argued that these fruitful advancements are inevitable. In addition to creating entirely new approaches, nanomedicine advances already existing ones.13,15

IN DENTISTRY, NANOTECHNOLOGY

Analogous to nanomedicine, nanodentistry's advancement would enable almost flawless oral health through the application of nanomaterials and biotechnologies, such as tissue engineering and nanorobots.11

Dentistry and tissue engineering

The treatment of orofacial fractures, bone augmentation, temporomandibular joint cartilage regeneration, pulp repair, periodontal ligament regeneration, and implant osseointegration are among the potential uses of tissue engineering and stem cell research in dentistry. Implants may now be placed that don't require a lengthy recovery period, are safer to support early loading, and are more physiologically and biologically stable than implants that have been utilized in the past thanks to tissue engineering.16,17
A significant portion of research in the field of tissue engineering is focused on studies pertaining to bone tissue regeneration. The arrangement of nanoscale fibers is similar to that of collagen fibrils and hydroxyapatite crystals in bone. Although biodegradable polymers or ceramic materials are frequently chosen in bone tissue creation, it is possible that they lack enough mechanical endurance despite their osteoconductive and biocompatible qualities. Recent research suggests that these materials' mechanical qualities can be improved by adding nanoparticles. The primary justification for favoring nanoparticles is that their dimensional range matches that of cellular and molecular components.4,18 Commercially available bone replacement materials created by nanotechnology are available.1,19, 20
Nanocrystalline hydroxyapatite can be used to create bone grafts with improved properties. Additionally, it was demonstrated that the hydroxyapatite nanocrystals enhanced the cell proliferation necessary for the repair of periodontal tissue.21

Nanotechnology on biomaterials and dental implants

The roughness of the natural bone surface is about 100 nm, hence on the surfaces of implants, these nano features matter. Nanoparticles on the implant surface have been shown to stimulate osteoblast proliferation.4,22 The biological response in the tissue is dependent on the implant surface being roughened at the nanoscale.23, 24
The effect of titanium implants treated with a nanostructured calcium surface coat on osteogenesis was studied; the implant's surrounding bone responded more to the nanostructured calcium coat. Numerous in-vitro studies have demonstrated that the implant surface's nanotopography has a significant impact on osteogenic cells and that the nanoscale surface morphology promotes osteoblast adhesion. Additionally, the surface morphology at the

nanoscale increases surface area, providing a larger implant surface area that is responsive to the biologic environment.25–28

Dental nanorobots

Medical robots are not expected to change dentistry anytime soon, but it's never too early to think about what might happen in the future.2 Dental nanorobots are able to move through tooth and surrounding tissues because they have unique movement mechanics. Nanorobotic functions can be controlled by nanocomputers previously programmed using acoustic signals utilized in ultrasonography.11

Dental nanorobots, also known as dentifrobots, are able to continuously prevent the buildup of calculus by cleaning organic residues from the occlusal surfaces of teeth. These nanorobots work by traveling around the supragingival and subgingival surfaces. When ingested, these nanorobots—which have a maximum speed of 1 to 10 microns per second—are safely rendered inactive.

Nanocomposite materials

The development of materials that match the color of teeth has been prompted by the growing interest in aesthetic restorations in recent years. One recent development in composite resins is the incorporation of nanoparticle technology into restorative materials.16,30 Nanotechnology has made it possible to produce nano-dimensional filler particles,31 which can be added to composite resins individually or in nanoclusters. Nanotechnology enables the production of nano-sized filler particles that are compatible with dental composites, so a greater amount of filler can be added into the composite resin matrix.32, 33 Traditional fillers are produced in large particles that are minified by pinning; however, these methods cannot reduce the size of a filler that is smaller than 100 nm.31, 33

After polishing, nanoparticles enable the creation of composites with a smooth surface and provide the material better aesthetic qualities. Such particles are easily shaped, and composite resins containing them have exceptional strength and abrasion resistance. Consequently, compared to composites using hybrid and microfill fillers, the application range of resins containing nanoparticles is greater.29, 34

As a result, a well-polished restoration surface can preserve its smoothness for a long time. Unlike hybrid composites, which allow large particles to be separated from the matrix during abrasion, only poorly attached nanoclusters are separated during abrasion in nanocomposites.29 The particles that form defects on the surface during abrasion are nano in size, which is smaller than the wavelength of light.33 Since particles in the visible light wavelength range (0.4 to 0.8 μm) do not reflect light, the material has superior optic character.29 The fillers in nano-composites have higher translucence because they are smaller than the wavelength of light, enabling the creation of more esthetic restorations with a wide variety of color options.33

Plaque accumulation and subsequent periodontal disease are caused by bacteria adhering to the rough surfaces of restorations.35 According to several reports, using composites with nanofiller resulted in significantly smoother surfaces than using other composites; this is because nanocomposites have much smaller sizes and contain much more filler than other composites.31, 35

By combining the mechanical and aesthetic qualities of hybrid composites with nanofiller technology, nanofill composites can now be produced. In-vitro tests have demonstrated the beneficial mechanical, esthetic, and physical properties of these composites. With these characteristics, the nanocomposite might be a tangible example of the perfect composite.31,33,35,37-39 However, long-term clinical studies are needed to confirm the successful in-vitro performance of nanofill and nanohybrid composites before they become widely used in routine practice.10,29,32, 40 Although previous clinical studies have shown that the use of nanocomposites is successful after 1- and 2-year follow-up, long-term clinical studies are needed to confirm this.

fake teeth made of nanocomposite

Nanocomposite-made artificial teeth have also been created. The nano-sized inorganic fillers in these prosthetic teeth are uniformly distributed and do not build up in the matrix. As a result, even when teeth erode, the surface's smoothness can be maintained. Experiments have demonstrated that artificial teeth made of nanocomposite material exhibit greater durability and abrasion resistance compared to acrylic and microfill composite materials. Additionally, composite resin artificial teeth that use nanofiller exhibit superior color retention.

Dental tissues as well as nanostructures

Enamel tissue has unique properties due to the absence of collagen and the inability to rebuild, even though apatite crystals are structured and accumulate with carbon dioxide to produce bone, cement, and enamel. The amelogenin protein's spontaneous self-assembly in nanospheres during enamel biomineralization is crucial for regulating the formation of apatite crystals with carbon dioxide. Other mineralized tissues, like cement and bone, can be formed using this method, which also makes use of nanostructures.

Nanomaterials for the delivery of periodontal drugs

By producing nanoparticles impregnated with triclosan, researchers have attempted to create an efficient and satisfying drug delivery method for the treatment of periodontal disorders. The administration of triclosan particles to the test area was found to reduce inflammation.5 Despite the fact that this study only looked at periodontal therapy, it did show that additional treatments might potentially use targeted medication delivery using nanomaterials. The Arestin® treatment, which involves inserting tetracycline microspheres into periodontal pockets and administering tetracycline locally, is the finest illustration of how this technology may be used in the future.5 In vitro research using toothpaste containing carbonate apatite nanoparticles demonstrated that dentin tubules were successfully sealed, which is critical for maintaining dentin sensitivity treatment.46

Using nanotechnology to stop dental cavities

a study that examined the bacteriostatic effects of silver, zinc oxide, and gold nanoparticles on Streptococci mutans, the bacteria that causes dental caries, found that silver nanoparticles had an antimicrobial effect in lower concentrations and with lower toxicity than the other nanoparticles.48 This was made possible by the use of toothpaste containing nanosized calcium carbonate.

digital images of teeth

Nanotechnology is also anticipated to lead to advancements in digital dental imaging procedures. High-quality images are achieved with a reduced radiation dosage in digital radiographies produced by nanophosphor scintilators.49 Nanotechnology applications in oral and maxillofacial surgery Particularly in tumor tissue surgery, selective cell manipulation and surgery performed using molecularly scaled instruments will be extremely advantageous.50 Future Domains in Which Nanotechnology Will Be Used in Dentistry Millions of active analgesic nanoparticles in a colloidal suspension are used in nanodentistry. into the patient's gingiva, and the dentist regulates the anesthetic's effectiveness by sending nanorobots into the gingival sulcus. An good modality for reducing anxiety and offering comfort to patients is nanorobotic analgesics. There aren't many of the side effects and issues that come with using regular local analgesic remedies. Significant advancements in dental repair through nanodental procedures have been made possible by technological breakthroughs in tissue engineering, genetic engineering, and tissue regeneration. It will eventually be feasible to create a new tooth in a lab setting. Researchers will soon be able to construct an autologous tooth with both mineral and cellular dental components in the dentist's office because to advancements in research.

Perfect treatment approaches will be made possible by nanotechnology for cosmetic dentistry. Any teeth that require non-biologic treatment, such fillings or crowns, will be repaired in a way that blends in perfectly with the native dentition using natural biologic materials. Another condition that can benefit from nanodental therapy is dentin sensitivity. Many therapeutic treatments only offer a transient solution for this prevalent, excruciating ailment. Dental nanorobots, on the other hand, can quickly and permanently heal patients with this ailment by sealing particular tubules using natural biomaterials in a matter of minutes. All periodontal tissues, including cement, gingival tissue, periodontal ligament, and alveolar

bone, can be directly manipulated by orthodontic nanorobots. In a few hours, they can painlessly twist, straighten, or realign the teeth vertically.
Artificial materials like sapphire or diamond can be bonded via covalent bonds into the outer layers of enamel to increase the strength and aesthetics of teeth. Despite the fragility of pure sapphires and diamonds, materials like carbon nanotubes can increase their ultimate strength. Sapphire is available in nearly every color on the color spectrum. This characteristic offers a cosmetic substitute for traditional teeth-whitening methods.
By using a mouthwash or toothpaste containing nanorobotic structures once a day, organic compounds will be continuously cleaned of calculus and will be broken down into innocuous, odorless components. These almost undetectable (1 to 10 µm) dental frobots will move at the speed of an amoeba.

1–10 µm/s. They are purely mechanical devices and may be produced at a low cost. Moreover, if they are swallowed, their action can be stopped safely. Specially designed dentifrobots identify and eliminate harmful bacteria from plaque and other areas, without interfering with the around 500 innocuous species that make up the regular flora. This helps to establish a thriving ecology. By removing the main contributor to oral malodor, bacterial putrefaction products, dentifrobots provide a constant barrier against halitosis. Thus, by implementing these regular dental practices from an early age, tooth loss and gingival disorders will be eradicated.11

conclusion:

Even though nanotechnology's impact on dentistry is restricted to the application of currently accessible materials, the quick advancement of research will guarantee that future improvements that seem unimaginable now are achievable. Future applications of nanotechnology's benefits will make it easier to achieve gains in oral health. Dental treatment will be enhanced by novel therapeutic and diagnostic methods, pharmaceutical strategies, and improved restorative materials.

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