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Review Article

# The innovative applications of therapeutic nanostructures in dentistry

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**Abstract**

Nanotechnology has paved multiple ways in preventing, reversing or restoring dental caries which is one of the major health care problems. Nanotechnology aided in processing variety of nanomaterials with innovative dental applications. Some showed antimicrobial effect helping in the preventive stage. Others have remineralizing potential intercepting early lesion progression as nanosized calcium phosphate, carbonate hydroxyapatite nanocrystals, nanoamorphous calcium phosphate and nanoparticulate bioactive glass particularly with provision of self-assembles protein that furnish essential role in biomimetic repair. The unique size of nanomaterials makes them fascinating carriers for dental products. Thus, it is recentlyclaimedthat fortifying the adhesives with nanomaterials that possess biological meritsdoes not only enhance the mechanical and physical properties of the adhesives, but also help to attain and maintain a durable adhesive joint and enhanced longevity. Accordingly, this review will focus on the current status and the future implications of nanotechnology in preventive and adhesive dentistry.


*Key words:* Nanoparticles; Caries prevention; Remineralization; Adhesive systems; Dental adhesion

Nanotechnology is earning tremendous publicity in the era of new adventure in multiple fields. Noble prize winning physicist Richard Feynman gave what is considered to be the first lecture on technology at the atomic scale, "There's Plenty of Room at the Bottom" at an American Physical Society meeting, 1959. The prime definition of "*Nanotechnology*" can be grasped as the science and engineering of functional systems at a molecular, or nanoscale (one-billionth of a meter) or one-ten-thousandth the width of a human hair. Accordingly, when a particle reaches maximum size of $1 \times 10^{-7}$ m, it is classified as nanoparticle or nanomaterial.[1,2] Such innovative technology becomes vastly used in medical community owing to its expanding applications especially in imaging and drug delivery to disease and cancer cells.[3] Extended applications of nanotechnology in the medicine field, presented an ulterior motive to the domain of dentistry. Nanodentistry possesses the versatility required to uniquely overcome some of the most challenging impediments to thorough oral health refinement and dental treatment success. Preventive dentistry, early diagnostics and dental therapeutics are considered the major dental disciplines which achieved refinement owing to the application of nanomaterials and nanotechnology.[4,5]

## Basic concept of nanotechnology

The matter behaves differently when spectacular elevation occurs in its surface area to volume ratio. Classical physics no longer applied to the behavior of the material which is now under the control of quantum laws. "Quantum theory" represents the basic of modern physics that explains the behavior of matter and energy on atomic and subatomic level. This fact gives the nanostructured material new abilities and properties that may be more favorable than the ones of the bulk material version. A good example is that some polymers, although being insulators in the bulk form, they become semiconductors at the nanoscale.

Today's scientists and engineers are finding a wide variety of ways to negotiate materials making at the nanoscale seeking the advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts.[1]

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There are two main techniques used in nanotechnology:

1. Top-down nanotechnology approach

This technique features the use of micro- and nanolithography and etching. Here, small features are made by starting with larger materials then "carving down" to make nanoscale structures in precise patterns. Materials reduced to nanoscale can surprisingly present different properties allowing unparalleled implementations. The reduced size of nanoparticles accompanied with elevated surface area to volume with concomitantly modified physical properties and quantum mechanics.[6]

2. Bottom-up or molecular nanotechnology approach (MNT)

This technique applies to building organic and inorganic structures atom-by-atom, or molecule-by-molecule. Here we are using the forces of nature to assemble nanostructures – the term "self-assembly" is often used. The self-assembling properties of biological systems, such as DNA molecules, can be used to control the organization of species such as carbon nanotubes, which may ultimately lead to the ability to 'grow' parts of an integrated circuit, rather than having to rely upon expensive 'top-down' techniques.[7]

## Generations of nanotechnology development

*Mihail Roco* of the U.S. National Nanotechnology Initiative has described four generations of nanotechnology development according to increased complexity and dynamics[8];

1. First generation products/passive nanostructures: are the materials designed to perform one task. Either; dispersed and contact nanostructures as colloids and aerosols or products incorporating nanostructures as coatings, nanoparticles, nanostructured polymers and ceramics.
2. Second generation products/active nanostructures: are to introduce active nanostructures for multitasking. Either; bioactive and producing health effects as drug delivery devices and bio-devices or physic-chemical active as the adaptive structures.
3. Third generation products/nanosystems:are nanosystems with thousands of interacting components. Guided assembling and robotics represent its evolutionary example.
4. Fourth generation products/molecular nanosystems are integrated nanosystems forming molecular devices by design, atomic design and emerging function of nanosystems that are developed.

## Dimensionality of nanostructures

Nanostructures can be classified on the basis of the grain structure and sizes; they are made up of according to *Hu* and *Shaw*,[9] into:

1. Zero-dimensional (0-D):

The nanostructure has all dimensions in the nanorange. For example: nanoparticles, quantum dots and nanodots.

2. One-dimensional (1-D):

One dimension of nanostructure is outside the nanostructure range as nanowires, nanorods and nanotubes.

3. Two-dimensional (2-D):

Two dimensions of the nanostructure are outside the nanometer range as coatings and thin-film-multilayers.

4. Three-dimensional (3-D):

Three dimensions of the nanostructure are outside the nanometer range as the bulk nanostructures.

## Nanostructures forms and shapes

Nanostructures come in different forms and shape provided that their dimension located in the range between 0.1 and 100 nm.[10]They are also of various compositions, thus offer vast variety of modified properties to facilitate innovative applications in dentistry.

### *Nanopores*

A nanopore is a very small hole with diameter located within the nanoscale range up to 100 nm. It can be produced as aperture in synthetic materials as silicon or graphene or as a puncture created via pore-forming protein in biological substrate. Silica fillers with nanopores proven to improve wear resistance in posterior composite restorations. Nanosized pores permit monomer flow in and out of the fillers, thus reinforcing composite.[11] Investigators revealed that when alumina particles interconnected using nanopore, the mechanical interlocking between fillers and matrix of composite restoratives will be enhanced without need for chemical bond. This would give promising hope for bioactive material creation following pores filling with various substances.[12]

### *Nanotubes*

Different types of nanotubes have been investigated for dental applications in a number of delightful fields. Carbon nanotubes, long thin carbon cylinders, made of graphite sheet folded into a cylinder and represent the most commonly used type in the dental field. Nanotubes provided either as a single-wall or multi-walled structure. It has unique mechanical properties in term of stiffness, strength and tenacity as well as outstanding bioactive capability.[13] Reinforcing dental composite using carbon nanotubes found to be able to enhance its flexural strength and modulus of elasticity with reduction of polymerization shrinkage and water resorption yielding more durable superior restoratives.[14] In addition, increased osteoblastic proliferation and alkaline phosphatase (ALP) activity have been detected when hydroxyapatite (HA)-carbon nanotube (CNT) composite coating was applied on titanium plates. Accordingly, CNT could yield a strong influence in reinforcement of HA coatings through improving the mechanical and biological tissue integration.[15]