Nanotechnology in Preventive Dentistry: A Review

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ABSTRACT

Background and Review: Nanotechnology is the science involved in design, synthesis, characterization, and application of materials and devices. Different approaches are used to introduce organic and inorganic nanoparticles in dentistry. Nanoparticles are used in preventive dentistry, strategies for the management of biofilm, demineralization inhibition and promote remineralization. Incorporation of different nanoparticles in fissure sealants, bonding agents, dentifrices, mouthwashes and glass ionomers were studied in vivo and vitro.

Conclusion: This article summaries the science of nanotechnology, that achieved and introduced in the dentistry and is promising that needs further research.

KEY WORDS

nanotechnology, dentistry, preventive dentistry, nanoparticles

INTRODUCTION

Nanotechnology is the science involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimension is on the nanometer scale¹.

Approaches to nano-dentistry²

A. Bottom-up approaches

Arrange smaller components into more complex assemblies. The covalent bonds of which are extremely strong and applied in:

1. Anesthesia
2. Local drug delivery
3. Nano diagnostics
4. Nano robotics dentifrice
5. Hypersensitivity cure
6. Dental durability and cosmetics

B. The Top Down Approach

Produce smaller devices by using larger ones in achieving precision in structure and assembly and applied in:

1. Nano composite
2. Nano Needles
3. Nano impression materials
4. Nano solutions

Types of nano particles

1. Inorganic nano-particles

- Hydroxyapatite (HA) or its derivatives modified with zinc, fluoride, or carbonate are mostly applied nano particles.
- HA does not exhibit cytotoxic effects and shows excellent biocompatibility³⁰.

2. Organic nano-particles

- Nano organic structures are components of several beverages and food stuffs.
- Milk containing casein micelles and lipid vesicles are similar to micelle like salivary structures involved in the formation of the pellicle layer.
- It may serve as carriers with high affinity to the pellicle to accumulate minerals and protective proteins at the tooth surface.
- Silver nanoparticles synthetic glass structures also have been described for possible application in preventive dentistry.

Nanoparticles in Preventive Dentistry

1. Silver nanoparticles

- Nano Silver (NAg) in composites and adhesive provide antibacterial effects on biofilms without impacting their main mechanical
The nano sized CaF<sub>2</sub> will be:

- NAg containing dental composite was shown to inhibit S. mutans growth when tested over a 6-month duration.
- A recent study showed better result in combined NAg with NACP in a composite to obtain antibacterial and remineralization capabilities.<sup>11</sup>

2. Zinc oxide nanoparticles (NZn)

- Similar to silver, ZnO has antibacterial effects against types of bacteria, including S. mutans.
- NZn was found more effective than conventional particles against Gram negative and Gram positive bacteria.<sup>14</sup>
- Antimicrobial mechanism of NZn is leaching of Zn into the growth media decreasing biofilm formation by<sup>15-17</sup>:
  - Modified cell membrane activity and oxidative stress that generate active oxygen species such as H<sub>2</sub>O<sub>2</sub> that inhibit growth of microbes.
  - Inhibiting the active transport and metabolism of sugars.
  - Disrupting enzyme systems by displacing magnesium ions essential for enzymatic activity of the of dental biofilms.

3. Quaternary ammonium poly ethylenimine nanoparticles (QAS)

(QAS-PEI)<sup>18,19</sup>

- Antibacterial agent of QAS is copoly-merized with the resin by a covalent bond, so it is immobilized in the composite and not released or lost over time.
- Gives a durable and permanent antibacterial capability to the dental material without significantly affecting the biologic balance in the oral cavity.
- QAS cause bacterial lysis by binding to the cell membrane.
- Adhesive systems containing QAS presented anti biofilm properties after 6 months of water aging.
- 1% QAS nanoparticles in composite exhibited strong bacteri-al effect against S. mutans sustained over 1 month without leaching out and with no alteration of the original mecha-nical properties of the composite.
- QAS-PEI nanoparticles were incor-porated in conventional glass ionomer and tested on S. mutans and Lactobacillus.

4. The nano sized CaF<sub>2</sub> will be:

- Effectively retained in the mouth due its high affinity to oral substances.
- A long-lasting source for fluoride than currently used NaF<sup>20</sup>.
- NCaF<sub>2</sub>, powder displayed much higher solubility and reactivity.<sup>21</sup>
- NCaF<sub>2</sub> are effective anticiaric agent by increasing the fluoride concentration and enhancing remineralization.
- Composites containing 20 0% NCAF, match the fluoride release rates of traditional resin modified GI due to a 20-fold higher surface area.<sup>22</sup>
- In vivo study indicate a 1 min application of this NCaF<sub>2</sub> rinse produces greater post rinse fluoride content (158 .mol/L) than a NaF rinse (36 .mol/L) within 1 hour.<sup>23</sup>

5. Nano hydroxyapatite and nano fluoro hydroxyapatite

- HA powders was added to materials for:
  - Remineralization
  - Improve the mechanical properties due to its excellent biocompati-bility and bioactivity.
  - A logical substitute for the natural mineral constituent of tooth.
  - Fabricate materials that imitate hard tissues
  - NHA were incorporated in resin modified GI
  - Toothpastes
  - Mouth rinsing solutions
  - Remineralizing pastes for use in preventive dentistry<sup>14,23</sup>.
- Apatite nanoparticles could become

Integrated in the pellicle layer at the enamel surface under oral conditions
  - Change the chemical composition and tenacity of the pellicle.
  - Then modify the subsequent bacterial adherence and the pattern of biofilm formation<sup>25</sup>.
  - 10% nNHA (60-100 nm) to Glass ionomer (GI) resulted in an increased resistance to demineralization and acceptable bonding strength compared with micro HA added to GI<sup>26</sup>.
  - Fluoride in NFHA increase the amount of fluoride release from the GI.
  - Besinis (2016) - Acetone was shown to act as a vehicle to enhance the capacity to infiltrate demineralized dentin with HA NPs<sup>24</sup>.

6. Carbon nanotubes

- Tubes are categorized into single and multi-walled nanotubes.
- Literature shows that single walled nanotubes have antimicrobial activity.
- Nano tubes may be used for water filtration and surface coating so used in dental water filtration systems and manufacture of dental equipment<sup>11,12</sup>.

7. Nano Encapsulated Chlorhexidine<sup>15</sup>

- Seneviratne CJ (2014) in study of Nano CHX demonstrated potent antibacterial effects on bacteria and mono species biofilms at the concentrations of 50-200.g/mL against Streptococcus mutans, Streptococcus sobrinus, Aggregatibacter actinomycetemcomitans and Enterococcus faecalis.
- Nano CHX effectively suppressed multi species biofilms such as S. mutans, F. nucleatum, up to 72 hours.

8. Nano catalysts (CAT-NP)<sup>19</sup>

- Lizeng Gao (2016) developed a novel multi-functional approach with both anti plaque and anti caries properties using nanoparticles with catalytic properties termed nanocatalysts.
- Their approach has 2 major biological effects:
  - CAT-NP are retained within 3D biofilm structure after briefing topical exposure.
  - CAT-NP rapidly catalyze low concentrations of H<sub>2</sub>O<sub>2</sub> at acidic pH to produce free radicals in situ that simultaneously kill bacteria embed-ded within biofilms.

Various nanostructures used in dentistry

1. Nanoparticles
2. Nanorods
3. Nanospheres
4. Nanotubes
5. Nanofibers
6. Dendrimers and dendritic copolymers
7. Nanopores
8. Nanoshells

Strategies of nano materials in Preventive dentistry

1. Interaction with bacterial adherence and oral biofilm formation.
2. Impact on de and remineralization.

Management of Biofilm

- Dental caries is caused by bacterial biofilms on the tooth surface<sup>40,41</sup>.
- Proteinaceous surface coating termed pellicle is formed on all tooth substrates.
- This is conditioning layer changes the properties of the substrate.
- Bacteria colonize the surface by adhering to the pellicle through adhesion receptor interactions and form a biofilm known as dental plaque.
- Maturation of the plaque is characterized by bacterial interactions, and increasingly diverse bacterial populations.
- Number of streptococci and lacto-bacilli bacteria increase, especially in the presence of dietary sugars.
- Bacterial produce acids as by products and cause demineralization below the surface of the tooth.
Approaches to minimize biofilm formation:
1. Establish a permanent modification or coating of the surface providing anti adhesive or easy to clean characteristics.
2. Adopt dentifrices and mouthwashes, that will be applied frequently.

Wear resistant nano composite surface coatings modify the tooth surface

- Easy to clean surface properties.
- These bio-compatible surface coatings have a surface free energy that facilitate the detachment of adsorbed salivary proteins and adherent bacteria under the physiological shear forces.
- Indicated for patients with high caries risk suffering dry mouth or for individuals who do not practice proper oral hygiene.
- To prevent the pathogenic effect of biofilm formation.

**NANO COAT - Composite Varnish**

- Nano Coat is revolutionary, nano filled, light cured, protective coating which effectively seals the surface to create smooth and glossy surface.
- It can be used on the glass ionomer and composite restorations and in difficult to polish areas such as posterior fissures or interproximal areas of indirect composite restorations.

**Fusion D. Sensy**

- Light Curing Nano Filled Fluoride Releasing Dentin Desensitizer Varnish and offer:
  1. Prevent second caries
  2. Biocompatibility
  3. Decrease tooth wear
  4. Superior dentin adhesive
  5. Cures hypersensitivity caused by Open tubules.
  6. Sealing of the dentinal tubules and reduces penetration of fluids into the tooth.

**Apatite nanoparticles alone or in combination with proteinaceous additives such as casein phospho-peptides**

- CPP stabilized amorphous calcium phosphate (ACP) nano complexes play a role in strategies for biofilm management and reduce bacterial adherence by binding to the surfaces of bacterial cells, the components of the intercellular plaque matrix and to adsorbed macromolecules on the tooth surface.
- CPP-ACP treated surfaces up to one week have been shown to delay the formation of biofilms.
- In vitro experiments have shown that non aggregated and cluster hydroxyapatite nano crystallites particles (average size 100, 10, 5 nm) can adsorb onto the bacterial surface, and interact with bacterial adhesion to interfere with the binding of microorganisms to the tooth surface.

**Demineralization, Erosion and remineralization**

- Demineralization starts at the nano level caused by either caries or erosion induced acidic challenges.
- It makes sense to supply small nano sized building units for optimized remineralization.
- This applies also for particle size interactions with bacteria and the bacterial membrane, where nano particles are much more effective than micro particles.
- For treatment of eroded tooth surfaces, carbonate HA nano crystals were synthesized by precipitation from an aqueous suspension of Ca(OH)2 by slow addition of H3PO4.
- They are quite similar as compared to dental apatite crystals.

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3780.


43) NANO COAT - Composite Varnish product profile, prevest denpro limited.

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