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Mini Review

Application of Nanotechnology in Dental Caries Management

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Abstract

Nanotechnology has been applied to dentistry for development of novel dental materials with advanced properties and anti-cariogenic potentiality. The prevention of tooth decay and the restoration of the formed cavities are currently challenges in dentistry. Recently introduced nanoparticles incorporated into the preventive therapeutic agents and dental restorative materials due to their great potential to reduce biofilm accumulation, decrease the demineralization of the hard dental tissues and enhancement of the remineralization process. This review is focusing on the progress in the development of nano-materials for applications in dental caries prevention and restoration.

Keywords: *Dental Caries; Nanotechnology; Prevention Dentistry; Nanoparticles*

Abbreviations

CPP: Casein Phosphopeptide; ACP: Amorphous Calcium Phosphate; TCP: Tricalcium Phosphate; HA: Hydroxyapatite; NM: Nanomeric; NC: Nanoclusters

Introduction

Dental caries is the most widespread oral health diseases affecting people worldwide throughout their lifetime, affecting 60 - 90% of school-aged children and the larger part of adults. The early manifestation of the dental caries process is the presence of small chalky white patches of demineralized softened tissues at the enamel tooth surface, often hidden in the fissures and grooves of teeth and difficult to be seen. Non-treated enamel caries, lead to destruction spreads into the underling softer and sensitive dentine layer. Dental caries could be also attack the cement of the root and cause gum recession and periodontitis [1].

The process of dental caries is produced by fermentation of sugars present in foods or drinks by action of cariogenic bacteria present in the dental plaque on the tooth surface and formation of acids. The produced acids lead to demineralization of calcium and phosphate from the tooth. Normal saliva acts as a remineralizing agent that provides a reservoir of minerals adjacent to the enamel, in addition to buffering and neutralization of the produced acids. Alternating demineralization and reminerlization occurs many times to enamel during every day. In case of imbalance in this process, when demineralization exceeds remineralization over times, there is a destruction of the enamel minerals leading to a cavity [2].

Prevention and minimally invasive treatment strategies of dental caries have become the main concern in modern dentistry. Management of dental caries includes both prevention and treatment of already destructed and lost tooth parts. Prevention is better than cure. Various dental caries preventive therapeutics demineralizing agents could be used including fluoride and non-fluoride application.

Fluoride varnishes which typically contain 5% sodium fluoride is a thick liquid can be painted to the enamel, dentin or cementum of the tooth. However, pit and fissure sealants is a thin plastic coating placed on the enamel occlusal surface of the teeth to create a thin barrier that prevent the access of plaque and acids to the enamel. Both fluoride varnishes and fissure sealants are considered as effective occlusal surfaces caries preventive tools [3].

Unfortunately, dental caries is non-avoidable disease, but it could be reduced effectively using a strictly well-established caries prevention programs dental and restorative care. In dental treatment of decayed teeth, removal of diseased tissue parts and teeth restoration with appropriate material. In spite of much effort in oral health promotion and preventive methods, dental restorations are still needed. Owing to the variety of dental restorative materials currently available, many appropriate materials could be used to restore dental carious teeth such as resin composite and glass ionomer and their modifications [4].

Recurrent caries are lesions at the existing restoration margins that become carious. The treatment of recurrent caries is done by replacement of the affected restoration. Prevention of recurrent caries, as well as other original caries, usually requires. Thus, a tremendous efforts should be done for production of restorative materials with high efficiency with anti-cariogenic properties [5].

Nanotechnology deals with nanostructures at the nanometer scale (0.1 - 100.0 nm) offers new approaches for dental caries management. Remineralization has the potential to be the major advance in the clinical management of the lost enamel surface. The use of nanotechnology simulated the natural biomineralization process that occurs naturally in dental enamel formation and repair. Hydroxyapatite is the primary inorganic component of hard dental tissues. Nano-hydroxyapatite has a great potential in providing preventive and therapeutic approach to dental caries. The properties of dental materials at nano-scale differ significantly from their properties at micro-scale. Newly introduced nanoparticles can be used to control the cariogenic biofilms formation and creation of new generation of dental restorative materials [6].

Antibacterial approach

Nanoparticles such as silver, zinc oxide and polyethylenimine have a great interest due to their excellent antibacterial effect which is mainly attributed to the increased surface area to volume ratio enabling greater exposure of atoms on the surface, which provides optimum contact with the environment. Moreover, the small size of these particles makes it easily to penetrate through cell membranes, thus affecting the internal cellular process of bacteria resulting in higher reactivity and antimicrobial effect [7].

Remineralizing approach

Remineralization is the process of introducing minerals into the carious lesion, typically calcium and phosphorus ions to arrest or reverse the caries progression. Moreover, changing tooth surface chemistry and reducing tooth susceptibility to destruction by acid attack and subsequent demineralization. There has been an increased interest in improvement of the remineralizing agents. Fluoride has been widely used as well-established remineralizing agent. The remineralization effect of topical application of fluoride depends on reducing the apatite dissolution than to promote remineralization of the lost minerals. Recently, nano silver fluoride varnish has been introduced due to their great remineralization capability in addition to antibacterial effect of nano silver ions which prevent bacterial DNA replications and decrease their adherence to enamel surfaces. Nano silver also inhibits the formation and growth of *Streptococcus mutans* biofilm and *Lactobacilli acidophilus* [8].

Casein phosphopeptide (CPP)-stabilized amorphous calcium phosphate (ACP) nano-complexes has an anti-cariogenic properties and act as a remineralizing agent. The high ionic concentrations of calcium and phosphorus will preserve the concentration gradient during the remineralization and ionic diffusion of the ions into carious lesions will occur. ACP precipitates from a highly supersaturated solution of calcium phosphate. It has been widely used in biomedical field due to their bioactivity, controlled biodegradation rate, high cellular adhesion and high osteoconductive potentiality. CPP has the ability to stabilize ACP into CPP-ACP complex through multiple phosphoseryl residues. The product is primarily used for treatment of tooth hypersensitivity. CPP-ACP binds plaque strongly, provides a large calcium reservoir and diffuses of free calcium ions slowly. Similar to the fluoride, CPP-ACP has shown powerful effects in decreasing dental caries [9].

Tricalcium Phosphate (TCP) nanofillers also could be used as remineralizing agent by addition to fluoride. The mechanism of action could be summarized as the follows: when TCP reach to the tooth surface, the saliva will activate the calcium complex, which is released by TCP and protected by fluoride ions. When released at the tooth surface, the high concentration levels of fluoride and calcium on the lesion will induce the remineralization [10].

Other biomimetic remineralization approaches for treatment of initial submicron enamel erosions are based on nano-sized hydroxyapatite (HA) particles which can be greatly improve the erosive demineralization of the natural apatite crystallites. Nano-sized HA with a size of 20 nm fits well with the dimensions of the nano-sized tooth defects at the enamel surface during acidic erosion [11].

Treatment of tooth hypersensitivity

Carbonate hydroxyapatite nano-crystals could be incorporated into the toothpaste for occlusion of the sensitive dentinal tubules and formation of a surface mineral layer or reparative secondary dentin for the treatment of dentinal hypersensitivity [12].

Nano-particle filled restorative resin composites

Nanotechnology offer a great advance in restorative resin composites because of the fact that addition of nanoparticles allows for greater loading of nano-fillers thereby enhancing the mechanical properties of the resin composites and allowing their usage in teeth stress bearing areas, such as occlusal-proximal cavities. The other reason for nano-fillers incorporation is that these particles are smaller than the wavelength of visible light which do not allow the detection of human eye to detect the presence of fillers. This has great effects on the optical property of these resin composites. Incorporation of nano-fillers improves the other the mechanical properties as wear resistance and polish ability [13].

Nano-composites are consisting of two or more materials joined together that include a resin matrix and nano-particles. These nano-composites processed basing on bottom up approach of nanotechnology in which two types of nanofillers are used: Nanomeric particles (NM) and nanoclusters (NC). In the most recent products, NM are nano silica particles which are non-aggregated with an average diameter of 20 - 75 nm, while the NC fillers contain about 2 - 20 nm zirconia-silica particle and 75 nm pure silica particle which are used in the resin matrix [14].

The recent application of the nanotechnology science to the field of dentistry has resulted in development of nano-filled resin composites with superior optical and mechanical properties as compared to other commercially available resin composites. Recently titanium oxide has been used as nano-fillers due to their porous nanostructured eliminating the need for coupling agent, as the resin matrix could be easily penetrates the porous nanofillers causing mechanical interlocking [15]. Moreover, nano-fissure resin sealant containing nanoparticles that facilitate the procedure of enamel fissure sealing due to their high flowability and enhanced mechanical properties [16].

Nano-filled bonding agents

These novel bonding agents contain silica nanoparticles, which do not tend to form cluster during storage and allows for strong bonding with minimal loss of the inorganic part of the enamel surface, leading to more resistant to oral cavity degradation [13].

Nano-filled glass ionomer cements

Modification of the conventional glass ionomers using nano-fillers is an active area of current research. Addition of nano-fillers to resin modified glass ionomers such as zirconia, nanohydroxyapatite–silica and titanium oxide have led to production of nano-filled glass ionomer cements with better mechanical properties which could be used in the restoration of primary teeth, simple cavities in permanent teeth and for bonding of orthodontic brackets with sufficient bond strength [17].

Conclusion

Bioactivity of restorative dental materials expands to include dental tissues reminerlization. The clinical application of nanotechnology can bring advancement into the practice of caries fighting. Bioinspired nanomaterials have moved from the research state to daily

dental application for improvement of oral health care products. It has been recommended that broad research be performed for improvement of the current preventive and caries management materials which has an awesome potential for enhancement of oral health. Bioactivity of restorative dental materials expands to include dental tissues remineralization.

Conflict of Interest

No competing interests were disclosed.

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