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Nanoparticles: A Boon to Dentistry

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Abstract

Nanotechnology has recently emerged as a rapid growing field with various biomedical science applications. With all types of nanoparticles, silver nanoparticle (AgNPs) have been used in medicine and dentistry due to their antimicrobial property. In dentistry, silver nanoparticles (AgNPs) have been incorporated into biomaterials to enhance their property and clinical efficiency. In this article, we discuss about the role of nanoparticles in dentistry and application of nanoparticles in prosthodontics.

Keywords: Application; Nanoparticles; Biomaterial; Antimicrobial property

1. Introduction

The revolutions in the field of science and technology have given promising results in the field of material science and one such advancement is nanotechnology. Nanoparticles is defined as those particles in which all the fields or diameter are in the nanoscale range, whereas nanomaterials are those for which atleast one side or internal structure is in nano scale. An engineered nanoparticle may be defined as any intentionally produced particles that has a characteristic dimension from 1 to 100nm and has properties that are not shared by non- nano scale particles with the same chemical composition. Nanotechnology is the science of manipulating matter measured in the billionths of a nanometer, roughly the size of two or three atoms. Nanodentistry is the science and technology of maintaining near perfect oral health through the use of nanomaterials including tissue engineering and nanorobotics. Among metallic nano particles, silver nanoparticle (AgNP) and recently evolving gold nanoparticle have antimicrobial properties and biological activity against bacteria, fungi and enveloped viruses. In dentistry, the direct application of AgNP would be aimed at disinfection and the prevention against pathogenic microorganism in the oral cavity. The main use of these particles is based on their prophylactic action. Therefore, this article gives an overview of use of various nanoparticles, their mechanism of action and its application in prosthodontics.

2. Discussion

Nanoparticles (NPs) can be obtained from natural sources or chemically synthesized or one of the by-products[1,2]. With the advent of nanotechnology, silver nanoparticles (AgNPs) have been synthesized, and they have shown potent antimicrobial properties[3,4]. The various types of nanoparticles are Nano pores, nanotubes, quantum dots, nano shells, nano rods, nano spheres, nanowires, nano belts, nano rings, nano capsules[5].The various nanoparticles used are :

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2.1. Silver

Silver nanoparticles have been found to be effective against bacteria, viruses and other eurkaryotes[6,7]. It has been demonstrated that Ag NPs arrest the growth and multiplication of many bacteria such as *Bacillus cereus*, *Staphylococcus aureus*, *Citrobacter koseri*, *Salmonella typhii*, *Escherichia coli*, *Klebsiella pneumonia* etc.

2.2. Gold

Gold nanoparticles (AuNPs) are small gold particles with a diameter of 1 to 100 nm. Once dispersed in water, AuNPs are also known as colloidal gold. Gold nanoparticles (AuNPs) have found application in and immunochemical studies for protein identification and are also used for DNA detection and cancer diagnosis [8,9].

2.3. Alloy

Silver flakes are widely used as silver has the highest electrical conductivity among metal fillers and their oxides have relatively improved conductivity [10].

2.4. Magnetic

Magnetic nanoparticles like magnetite and maghemite have been actively studied for their use in treatment of cancer, gene therapy, DNA profiling, guided drug delivery system and MRI [11].

2.5. Copper

As the copper as antibacterial and antifungal activity, the application of copper nanoparticles has been quite a focus in health related issues. The antimicrobial activity is induced by their close interaction with microbial membranes and their metal ions released in solutions.

2.6. Zinc compound

Zinc nanoparticles have antibacterial, anti – corrosive, antifungal and UV filtering properties.Nano zinc decrease biofilm formation by inhibition of the active transport and metabolism of sugar as well as disruption of enzyme system by displacement of magnesium ions essential for enzymatic activity of dental biofilm [12].

2.7. Titanium dioxide

Titanium dioxide nanoparticles have been use in biomaterials in order to induce antimicrobial properties.They have properties such as white color, low toxicity, high stability and efficiency along with availability and low cost made them to use in dental materials [13].

2.8. Quarternary ammonia nanoparticles

Quarternary poly ethvlenimine nanoparticles as antimicrobials incorporated in composite resins have been developed. The hydrophobic nature and the cationic surface charge of these particles add on to their antimicrobial activity.

3. Properties of silver nanoparticles

The AgNPs have exhibited a broad spectrum antibacterial effect on both gram positive and gram negative organisms and on various drug resistant strains. The most common mode of action of AgNPs is by continuous release of free silver ions, which is considered the mechanism of killing microbes [14]. This free silver ion cause interruption of Adinosine Triphosphate (ATP) molecules and prevent DNA replication or formation of reactive oxygen species. AgNPs act by induction of reactive oxygen species production and hydroxyl radicals which both are main components that is responsible for oxidative damage [15]. AgNPs also damage the membrane and cell walls, interferes in the respiratory chain, exhausts the level of intracellular Adenosine triphosphate and shatters nucleic acid [16,17]. This mechanism of action varies based on the size and shape of the nanoparticles and with the different target species.

3.1. Two hypothesis was put forward for bacterial activity of Ag

- AgNPs binds to sulfur containing proteins in biological molecules, resulting in pore formation in cell membrane or defects in cell membrane through the formation of reactive oxygen species which causes permeability and death.

- It interacts with phosphorus containing compound such as DNA and various cellular enzymes such as cytochrome oxidase and NADH succinate dehydrogenase that affects cell division process leading to cell death.

The Antiviral mechanism of AgNPs is not completely known but it is suggested that AgNPs may bind with outer protein of viruses inhibiting their binding and replication.

4. Role of nanoparticles in dentistry

Nanoparticles have been successfully used in dentistry in various forms for administering local anaesthesia to the treatment of oral cancer. Due to the biocidal property, anti-adhesiveness and delivery capability of nanoparticles, they are being explored more to prevent formation of dental biofilm within the oral cavity. It acts more efficiently on microbial membranes as they have greater surface – to – volume ratio and they also provide large surface area for antimicrobial activity. Nanoparticles can be used as device coating, as topical agents and also can be incorporated within dental material [18,19].

Nanoparticles are used in various restorative dental materials like cavity liners, pit and fissure sealants, core build up, cements for orthodontic procedures, provisional restoration, indirect restoration, root canal posts[20]. Silver hydrosol mixed with alginate impression material will have antimicrobial properties, which reduces the microbial cross contamination to the poured stone model from infected impression [21]. Silver nanoparticles can be used in controlling of dental caries progression as the silver ions infiltrates carious lesion and precipitates which results in enamel hardening. Silver nanoparticles is also used in root canal irrigation solution which directly acts on the pulp canal microbes which is as effective as 5.25% NaOCl in eradication of enterococcus faecalis and streptococcus aureus[22]. Amalgam has good mechanical property. Composite is used as restorative material and also to seal crown and bridge. Gold is a harmless, precise and rigid metal which is considered as ideal metal for prosthesis. In removable prosthesis stainless steel is used as framework and clasp[23]. Although these methods are used in dentistry for many years, they too have some disadvantages. The main disadvantage of amalgam is that the presence of mercury which is harmful to our body[24]. Composite is highly sensitive to cold while ceramic are extremely hard and it can sometimes break. To overcome these disadvantages nanoparticles are introduced in the field of dentistry [25,26]. The most commonly used nanoparticles are silver which is followed by carbon and titanium dioxide (TiO_2). The incorporation of nanoparticles improve the quality and lifetime of the products.

The recent advances in the use of nanoparticle in the field of dentistry is invention of nano toothbrush which is done by incorporating nano gold or nanosilver colloidal particles in between the bristles. It effectively removes the plaque and has antibacterial effect which significantly reduces the periodontal disease[27]. The use of nano calcium fluoride which is added to mouthwash to reduce Caries activity. The heat cured PMMA denture base which is incorporated with zirconium oxide nanoparticles showed improved hardness, flexural strength and fracture toughness. While comparing conventional luting cements with the nanoparticles incorporated luting cements, the nanoparticles impregnated luting cements has showed increased bond strength between enamel and dentin, it also reduced the polymerisation shrinkage[28].

5. Application of silver nanoparticles in prosthodontics

Silver nanoparticles in dental resin composite is considered as antimicrobial component.

Addition of low percentage of silver – zinc reduces the microbial contamination of acrylic resin denture base and other dental prosthesis.

5.1. Tissue conditioner

Tissue conditioner or soft liners are used to treat inflamed mucosa supporting a denture and bring back the tissue to health. Tissue conditioner is used in relining of ill-fitting denture to allow the tissues to return to normal. As tissue conditioner degrades over time and sometimes susceptible to microbial colonization. Incorporation of silver nanoparticles helps in reducing microbial colonization[29]. In patients with sharp alveolar ridges, inflamed mucosa and resorbed ridges, the tissue conditioner is used for relining the dentures which is modified with silver nanoparticles to halt the growth of various bacteria and fungi. Tissue conditioner are incorporated with zeolites to make them antimicrobial. Zeolites are aluminum silicate crystalline structures. The cations of Ag and Zn are found within the empty spaces of zeolites. These cations are exchanged over a period of time with other cations. These free cations contacts the environmental micro organisms which inactivates the vital microbial enzymes, interrupting the RNA replication and blocking their respiration by an oxidative process[30].

5.2. Implants

Dental implant is one of the most predictable treatment option for the replacement of missing tooth. Now implants are preferred more than the traditional prosthesis or fixed partial dentures. But there is a common problem with implant which is formation of biofilm over the surface of the implant. These biofilm causes infection and inflammation at the implant site and it leads to implant failure. To overcome this, the surface modification of titanium implant with silver nanoparticles have been done, as silver nanoparticles is well – known antibacterial, antimicrobial agent. In study performed by zhao et al[31], silver nanoparticles were incorporated into the titania nanotubes(TiO_2 – NTs) on titanium implants, by the process involving silver nitrate immersion and ultraviolet radiation. The antibacterial effect against staphylococcus aureus was assessed and results showed inhibition of planktonic bacteria during first several days. The silver nanoparticles coated with titanium implants also prevented bacterial adhesion for upto 30 days, which is considered as sufficient time for the prevention of post implantation infection. Silver nanoparticles can kill staphylococcus aureus and pseudomonas aeruginosa at even low concentration, which also have no significant cytotoxic effects on osteoblastic cells[32]. In addition, titanium embedded silver nanoparticles enhances bone mineral density, bone formation with no harm to tissue adjacent to dental implants[33]. Alternatively, implants treated with silver plasma exhibited better osteointegration than those treated with acids[34].

5.3. Maxillofacial prosthesis

Maxillofacial prosthesis as a phase of dentistry that artificially replaces parts of the face after injuries or surgical intervention. These maxillofacial prosthesis are more prone to contamination and also infection by Candida albicans. Candida albicans poses challenge to the maxillofacial prosthesis which is fabricated using silicone material as they causes degradation of the material and infection of the surrounding tissues. The maxillofacial prosthesis which are used for nasal, midface or combination of facial prosthesis with obturator extended intra orally are exposed to body fluids such as saliva, nasal secretions. These prosthesis are more prone to surface colonization of micro organisms which also cause subsequent degradation of material and complex biofilm formation over the maxillofacial prosthesis. Thus coating the maxillofacial prosthesis with the silver nanoparticles reduces the fungal colonization and thereby reduces fungal infection.

5.4. Denture base resin

Poly methyl methacrylate (PMMA) acrylic resins are used for the fabrication of dentures. These resin which has rough surface attract potentially harmful micro -organisms [35]. One of the main micro-organism which colonize in these resins is Candida albicans. To control the colonization of candida albicans various mouthwashes and denture cleansing agents were used but it failed to achieve complete elimination of these pathogen [36]. To control this, AgNPs have been incorporated into the resin materials. Acosta – Torres et al, developed a poly methyl methacrylate (PMMA) containing 1µg/ mL of AgNPs and they compared this with conventional poly methyl methacrylate (PMMA). PMMA – AgNPs showed less Candida albicans adherence compared to conventional PMMA. PMMA – AgNPs also does not showed any cytotoxicity or genotoxicity. Addition of AgNPs to PMMA reduced the surface roughness and it reduces the addition and colonization of Candida albicans over the dental prosthesis [37, 38]. On the other hand, addition of AgNPs caused color changes in prosthesis [39]. The color change is due to the plasmatic effect of AgNP through electronic propagation as on electromagnetic wave in the visible light spectrum [40].

6. Conclusion

Nanoparticles play an important role in modern medicine as well as in dentistry. Nanoparticles have many unique properties with particles of nano scale. Thus various types of nanoparticles were used in experimental and in vivo studies. AgNPs display distinctive biological properties unlike other dental biomaterials. AgNPs due to their antibacterial, antiviral and antifungal properties, they possess distinct advantage and great prospective. AgNP has also been proved to be biocompatible with mammalian cells, suggesting that it's application on dental materials does not cause any threat to human health.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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