Future impact of nanotechnology in dentistry

Abstract

Dentistry is one of the most important clinical practices provided to the public community in order to maintain good oral health. There are many challenges faced in dentistry especially involving the material used to treat different types of diseases. There are many limitations with the materials currently used in dentistry which has led to the introduction of nanoparticles. Nanoparticles play a major role in dentistry in order to improve the properties of materials. Silver nanoparticles are the most frequently used due to their antimicrobial properties which provide extensive suitability. However there are disadvantages to the use of nanoparticles which will be discussed including toxicity and hazards. Furthermore, the future implications of nanotechnology will be included.

Introduction

The biggest challenge that is faced every day in dentistry is maintaining good oral health. Distinct materials in previous years were used to treat different types of diseases even though treatment success has its own limits due to the biomaterials used and its features. These limitations can be avoided with the incorporations of nanoparticles (NPs) in dental applications such as endodontics, periodontics, tissue engineering, oral surgery, and imaging (Ranjeet A. Bapat 2018).

Nanoparticles have very eccentric properties and this includes their surface: volume ratio, antibacterial exploit, physical, mechanical, and biological characteristics, and distinctive particle size. The dream of nanotechnology was principally presented in 1959 by the famous physicist Richard Feynman in his presentation “ There’s Plenty of Room at the Bottom (Patil 2008). This marked out that synthesis was possible with direct manipulation of atoms. This review provides the insights of several applications relating to nanoparticles in dentistry, together with the benefits, limits, properties, actions and future potential.

History of Nanotechnology in Dentistry

Nanoparticles for dental composites are continuously evolving, given this, a sharper focus has been taken into account with reformulations. There are a number of compounds that have been used in the field of dentistry for teeth to be protected by. The main conventional materials that have been used are amalgam, nickel/cobalt chrome alloys, glass ionomer, gold alloy, ceramics and composite resins. These materials have advantages and disadvantages with their own use. An example being Amalgam is used for fillings in teeth because it contains good mechanical properties. A polymerization lamp is used to seal crown and bridges permanently through insertion of the oral cavity. The advantages of using this material is that it is durable and can provide great resistance for corrosion on the surface, as well as it is easy to manipulate. Another benefit it takes less time to get placed compared to other materials and it prevents from bacteria leaking, as well as it lasts long and is cheap. The disadvantages to the use of this material is tooth tissue may be disrupted, qualities of aesthetic are reduced, allergic responses may occur and mercury is a component which has toxic effects.

Glass Ionomer provide visual beauty where it prevents decay by releasing fluoride and allows the tooth to be less sensitive. The disadvantages is the limitations, the material becomes rough overtime and can result in plaque buildup causing periodontal disease (Priyadarsini S 2018). Most of the conventional materials used in dentistry have limited usage and it can become very expensive too. Due to these disadvantages nanoparticles have been introduced in dentistry. The nanoparticles have qualities in which they can improve the properties of products. Nanoparticles are small in size which allows for greater surface area and this leads to improved antibacterial effect. Silver nanoparticles tend to be the main focus in dentistry especially due to their antimicrobial properties.

Silver nanoparticles

The most commonly used nanoparticles in dentistry are silver nanoparticles due to their antimicrobial properties providing extensive suitability in dentistry. Silver nanoparticles are spherical with a mediocre size of 30 +/- 10 nm and demonstrate to be effective in prosthetic materials, adhesives, implants as well as prevent biofilm forming on the teeth and osteogenic induction (Elkassas D 2017). It has been recently accomplished to form AgNPs by controlling their size and morphology, along with high homogeneity and specific target functions.

Mechanism of silver acting on bacteria

There have been various recognition within the aspects of the antimicrobial action that nanoparticles provide, however the mechanism has not yet been fully clarified. Silver ions have the ability to act on different structures held within the bacterial cell. These ions mainly seem to adhere to the cell wall and cytoplasmic membrane by electrostatic attraction and affinity to sulfur proteins. Given this, the permeability of the membrane is enhanced and led to disrupting these structures. In Gram-negative bacteria, porins in the outer membrane are also involved in the uptake of AgNPs. Bacterial molecules that are capable of being damaged by AgNPs include DNA, proteins and lipids. AgNPs furthermore motivate oxidative stress response that triggers bacterial cell damage and increases dephosphorylation of tyrosine residues on bacterial peptide substrates, preventing bacterial growth and viability.

Bacteria in oral cavity truly prefer being systematized in biofilms and this convenes better conditions for growth, immunological evasion and resistance to antibiotics. Especially with dentistry, preparing nanoparticles must include the biofilm architecture and mechanistic aspects of AgNPs. The properties within the nanoparticle might affect its efficiency and restrict its mechanism of exploit. The vital aspects that should be considered in this construction: (i) the diffusion of nanoparticles in biofilm show inverse relationship between efficiency and size; nanoparticles in excess of 50nm are not capable of penetrating the biofilm due to the virtual self-diffusion coefficients in the biofilm, and this decreases exponentially with the square of the nanoparticle diameter. Another important aspect, (ii) charged nanoparticles are not able to diffuse as easily compared to neutral particles and this is mainly from the presence of phosphoryl and carboxyl groups on the surface of the bacteria giving the cell surface an electronegative character (Noronha V. T 2017). The concentration in formulations is mainly prearranged by the overall quantity of Ag (metallic Ag and Ag+), and the value is provided in g/mL. The universal procedure undertaken to determine the total amount of Ag (per mL) is ICP (inductively coupled plasma spectrometry)

Application of Silver nanoparticles in nanocomposites

AgNPs have been integrated into tissue conditioner, denture resins, and other biomaterials. Antifungal effect in contradiction of Candida albicans with the aid of AgNPs have proven to be effective when added to poly(methyl methacrylate) (PMMA) resins for dentures and silicone-based soft liners. This type of bacteria is able cause denture stomatitis and mucosal infections. Acrylic resin nanocomposites and AgNP (~38nm) have similarly shown resilient antimicrobial effect against E. coli along with improved flexural strength and modulus. It should be considered in methods to introduce AgNPs into innovative experimental PMMA formulations to reduce microbial adherence and establishment in prosthetic devices in general. An example that relates to this is when AgNPs were incorporated in PMMA denture resins to conjugate antimicrobial properties for comprehensive denture wearers to control infections in oral mucosal tissues. It showed that AgNPs were firmly amalgamated in the acrylic resin in the area of where the denture was composed, and no release of nanoparticle was detected while the denture storage was in deionized water within the 120 days. Another practical method contained AgNPs in acrylic resin denture base material which led to enhancement of storing modulus E' and loss tangent Tan δ values in concentrations equal to or higher than 2 wt%. This alteration led to resins gaining improvement in the material strength.

Implants modified with Silver nanoparticles

Implant coatingsare a way to obstruct bacterial adhesion to their surfaces and it also allows for stimulation of osseointegration and fibroblast increase.

AgNPs have been tested in various ways as well as other antibiotics in coating formulations to show favourable results relating to antimicrobial activity. AgNPs have been used in combination with tantalum nitride for coating of titanium substrates. The composites with a silver concentration of 21. 4 wt% displayed substantial antibacterial effect against Staphylococcus aureus.

During biocompatibility tests that were used to evaluate growth of human gingival fibroblasts, the samples that were coated showed greater cell viability and proliferation when they were exposed to AgNPs than uncoated samples (Bapat R. A 2018). Overall, AgNPs were able to demonstrate that it contained properties which prevented contamination of the interior surface of the implantation by C. albicans, produced by the implant/abutment microgap permeation.

Toxicity of Silver nanoparticles

Silver nanoparticles have contributed widely within dentistry, enhancing antimicrobial properties due to increase in surface area in nanoparticle formulation. It has been evident that these properties are also against antibiotic resistance microbe proving synergistic effect with conventional antimicrobials. Even with all these undeniable contribution towards oral health of silver nanoparticles, there are serious opposing actions that must be considered in order to fulfill its safety requirements.

Adverse effects of free Ag^{+} in industrial wastes remain noticeable in line for the occurrence of argyria (skin discoloration) and argyosis (discoloration of eyes) as well as other related side effects on renal, hepatic, intestinal, respiratory systems (Bapat R. A 2018). In addition, it has been reported several times that there is evidence of toxicity in AgNPs which can be due to co-exposure with fluorides, or in arrears to cytotoxicity. Preclinical studies on rats demonstrate a rise of toxin buildup in females particularly in the liver, kidney, colon, and jejunum when associated with males. Additional studies have deep-rooted buildup of silver in the glomerulus of the female rat kidneys, as reinforced by the colourations throughout histopathological studies. Also the affinity of silver to sulphur, selenium and chlorine inhibit in signal transduction. Many in vivo studies indicate that silver nanocarriers deposit in parts of the liver to create its hepatic harmfulness. Histopathological analysis can reveal the complex rate of hyperplasia of bile duct when including or excluding necrosis, coloring and fibrosis.

Hazards of Nanotechnology

Nanotechnology is emerging everywhere in science and it does provide many solutions to the problems that we face. Nonetheless, nanotechnology is not always perfect (Schmalz G 2017). Smaller particles tend to become more toxic than larger particles and this has been evident in certain experiments. They have shown that nanotechnology is able to function as venom to the populations that we habitat and nanoparticles are recognized to biomagnify in animal organs. Researchers are correspondingly troubled about soil and plant life. Nanoparticles may lead to lung injuries (Sasalawad S. S 2014). With balancing the risks and benefits, it is possible to maximize applications in medicine deprived of harming the public health as well as the environment.

Future perspectives

As mentioned previously dental materials containing silver nanoparticles present effective antimicrobial properties. However, there is a lot more research that needs to be undertaken in order to discover new information that could be of important use. The experiments that are the most significant used in studies involve the application of bench results on in vivo studies due to laboratory conditions not reproducing oral conditions. Other aspects that need to be investigated include long term effectiveness of AgNPs applied on dental materials, where an enduring antimicrobial potential is required of them (Correa J. M 2014).

Conclusion

Nanotechnology has achieved to produce a strong impact in the field of dentistry. A diverse number of nanostructures have been combined into dental materials with innovative applications. With the promising advantages observed in nanoparticles in dental therapeutics, it is possible to conclude that there is a domination of prolonged endorsement especially in the field of caries prevention, biomimetic repair and dental adhesion of composite medicine. Conversely, further investigations are important to be undertaken so that a better understanding is provided with the possible risks for any human health and environment.

References

1. Correa J. M, *Silver Nanoparticles in Dental Biomaterials,* 2014, accessed 9/10/2018, .

2. Sasalawad S. S, *Nanodentistry: The next big thing is small,* 2014, accessed: 3/10/2018, .
3. Schmalz G, *Nanoparticles in dentistry,* 2017, accessed: 10/10/2018, .
4. Bapat R. A, *An overview of application of silver nanoparticles for biomaterials in dentistry,* 2018, accessed: 3/10/2018, .
5. Noronha V. T, *Silver nanoparticles in dentistry,* 2017, accessed: 10/10/2018, .
6. Elkassas D, *The innovative applications of therapeutic nanostructures in dentistry,* 2017, accessed: 10/10/2018,
7. Priyadarsini S, *Nanoparticles used in dentistry: A review,* 2018, accessed: 1/10/2018, .
8. Ranjeet A. Bapat, *The use of nanoparticles as biomaterials in Dentistry,* 2018, accessed: 1/10/2018,
9. Patil M, Mehta DS, Guvvas, *Future impact of nanotechnology on medicine and dentistry,* 2008, accessed: 1/9/2018, .