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REVIEW ARTICLE

Nanobiomaterials in dental diagnostics: A review

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Abstract

Nanotechnology has revolutionized the diagnosis and treatment of the human disease ever since its discovery in 1970s. Conjugation of metal nanoparticles like gold nanoparticles has been successful performed in the biomedical application. The present article summarizes the most commonly used nanomaterials, their properties, and their applications.

Introduction

The science and technology of nanoscale devices and materials are significant evolution that is little while outcome for the betterment of dental aid. Nanodiagnostics are a nascent field of diagnostics in health protection and dental care. Salivary diagnostics powered by nanotechnologies, computerized and mechanized, conveyable, economical, effective, and quick biological and chemical detection has become possible due to nanotechnology and nanobiomaterials. Nanobiomaterials are materials with basic structural units grains, particles, fibers, or other constituent components smaller than 100 nanometer in at least one dimension, have evoked a great amount of attention for improving disease prevention, detection, and cure. Nanotechnology is defined as design characterization, production, and application of structure device and system for controlled manipulation of size and shape at the nanometer scale. On a miniature scale, salivary-based detection tools provide an easily available, non-invasive diagnostic medium for a rapidly widening range of diseases and clinical situation. These diagnostic tools make it possible to achieve accurate and concurrent investigation of various infections. *Ex vivo* investigative devices, *in vivo* imaging nanotechnologies, nanoprobes for sensing, imaging and disease detection, implantable nano-enabled biomedical device, implantable biosensors, nanoindentations as a tool for understanding mechanical properties of materials in dentistry are some of the commonly used nanodiagnostic tools. With the use of nanobioconjugates, the metal nanoparticles like gold nanoparticles have been successful performed in the biomedical application in 1970s after the discovery of immunogold labeling by Faulk and Taylor.[1]

Gold Nanoparticles

Gold nanoparticles are a type of metallic nanobiomaterial. In general, synthesized gold nanoparticles are with different structural units such as nanosphere, nanorods, and nanoshells. The shape of gold nanoparticles is a significant factor for their optical properties. Due to distinctive optical features of gold nanoparticles, it is extentively applicable in bioimaging and biomedical applications. By different synthesis process, different type of gold nanoparticle has been synthesized. An optical phenomenon called surface Plasmon resonance, in which at a specific wavelength of light there is collective oscillation of electrons on the surface of gold nanoparticles produce strong extinction has been achived by modifying gold nanoparticles size, shape, surface, and agglomeration state.[2,3] The AuNps surface has been controlled by ligand functional activity to selectively bind biomarkers. Gold nanoparticles has ability to produce heat by converting absorbed light into heat by non-radiative transitions.[4] Gold nanoshells have been shown to improve contrast in optical coherence tomography *in vivo* and for tumor therapy by near-IR photothermal ablation combining diagnostic and treatment applications.[5] PEGylated nanogels containing gold nanoparticles have been employed as a fluorescence-based apoptosis sensor, where activated caspase-3 leads to release of FITC molecules.[6] The most common approaches are controlled attachment thiolated DNA (deoxyribonuclic acid) and activation of AuNps provides a markable platform for specific bioimaging and detection. DNA hybridization activity of single stranded DNA conjugated AuNps used as probes for DNA detection. Other approaches were reviewed[7,8] that dispense a promising use of gold nanoparticles in therapeutic applications. Quantum dots (QD) are novel semiconductor nanocrystals with various applications in the research and treatment of cancer. QD owe their fluorescence emission to electron excitation. They are composed of an inorganic elemental core (e.g., cadmium and mercury) with a surrounding metal shell. Recently, QD have found applications in composites, solar cells (Gratzel cells), and fluorescent biological labels (for example to trace a biological molecule) which use both the small particle size and tunable energy levels. Recent advances in chemistry have resulted in the preparation of monolayer-protected, high-quality, monodispersed, and crystalline QD as small as 2 nm in diameter, which can be conveniently treated and processed as a typical chemical reagent.[9] A research done by Hahn *et al*.,[10] they focused on detection of single bacterial cell by QD. This research is advantageous, as CdSe/Zns were assembled and then become functional with attached streptavidin and antibodies. In addition, Edgar in his research used biotinylated bacteriophages to develop biotin-tagged phase QD nanocomplexes.[11] A study done by Dwarakanath *et al*. based on shifts of emission spectra from QD shows efficient biological detection.[12] Earlier studies open new avenues for application of QD as bioimaging tools.

Dye-doped Fluorescent Silica Nanoparticles

The commonly synthesized various types of silica-based nanobiomaterials are used for biological assessment. The different types of silica nanoparticles are with different basic structural unit and surface charge. Surface charge is one of the most important characteristics in terms of mechanical and biological property of silica nanoparticles. By changing surface charge, there are differences in its dispersibility which change the particle action and its functional properties used for biomedical application. According to Yan *et al*. most of the silica-based nanobiomatrials being used in bioimaging.[13] As mentioned, there are various nanobiomaterials based on silica, but dye-doped silica nanoparticles due to their facile synthesis techniques show relatively good result in reference to detection of human pathogens like bacterial infections. In various research, it was observed that due to ability of trapping dyes within silica matrix and thereby reducing leakage of dye by forming significantly effective barrier leads to modification in the reduction of photobleaching and photodegradation. The accumulation of a range of dyes with in a single nanostructure leads to significant ability to produce modified nanosystems. In a research conducted by Yao *et al*., he observed that because of more trapping of dyes with in silica nanoparticles the emission spectrum of dye-doped silica nanoparticles are equal to 39 quantum-dot nanoparticles. One more property of dye-doped fluorescent silica nanoparticle has to activate the surface by joining various functional groups that provide the extra strength for nanoimaging and bioanalysis. With the use of conjugate such as targeting ligand or a protecting molecule, the functionality of dye-doped silica nanoparticles improved for biomedical application. As stated above, silica nanoparticles applied in various therapeutic applications although not significantly applied for bacterial investigations. Fluorescent silica nanoparticles named Flo Dots were discovered by Yao *et al*. in 2006. Flo Dots found equivalent in fluorescence intensity to 39 QD having an emission of 695 nm. Nanobioconjugates Flo Dots used for real time and accurate detection of single bacterium. Yao *et al*. conducted a study in which they take *Escherichia coli* as experimental bacterial cell and use antibodies that targeting antigen present on bacterial surface and they analyzed that detection of bacteria was possible within 20 min and it was monitored by plate-counting method.[14] In a study conducted by Wang *et al*., he used multicolored fluorescence resonance energy transfer (FRET) silica nanoparticles by taking a proportion of three dyemolecules. FRET is an acronym for FRET. FRET silica nanoparticles offer remarkable efficiency, brightness, and photostable luminescent diagnostic nanosystem.[15] This research shows the efficiency of multiplexed bacterial monitoring system, which leads to rapid and specific detection of single bacterial cell. These all are signs that we are in the midst of an explosion of new health-related technologies. In addition to specific advances in health research, traditional sciences and technologies are undergoing significant changes that could have a far-reaching impact on dental diagnostics.

Carbon Nanotubes

Carbon nanotubes (CTNs) have become popular in the recent times due to their distinctive physical characteristic and chemical nature. Their small size, ability to pass through leaky vasculature, structural integrity, intrinsic stability, biocompatibility, and ease of conjugation with diagnostic and therapeutic agents make them popular nanoparticles for use.[16]

They have been widely utilizing in the detection as well as therapy of cancer caused by human pathogens like bacterial infections. Studies proving their efficacy have been performed both *ex-vivo* and *in vivo* techniques.[17,18]

Kim *et al*. analyzed the photothermal antimicrobial efficacy and diagnostic efficiency of self-assembling CTNs in bacterial infection. They showed that the diagnosis and destruction of the bacteria was brought about by the use of dispersed, shortened CTNs which help in the clustering of bacteria.

Subsequent exposure to the inherent infrared emission led to the destruction of the pathogens by the generation of singlet oxygen.[19] CNTs conjugated with pulse lasers accumulated at the site of infection as photothermal contrasting agents and thus could be easily detected by single cell in real time polymerase chain reaction.[20]

Conclusion

The introduction of nanotechnology and its application in medical field led to major advancements, especially in detection and therapeutic purposes of various infections including cancer. Although few limitations of these new methods such as high cost, labour intensive, and extended time, the advantages over the conventional techniques are many. These methods are more specific and sensitive. Use of nanoparticle in biomedical field definitely offers a promising future.

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