Quantum dots in Dentistry

What are Nanoparticles and applications in dentistry

Add images or charts as needed.Nanoparticles are particles with components smaller than 100 nm in at least one dimension. They can be atoms clusters, grains, fibers, films, nanoholes, or composites. Nanomaterials are referred to as sheets in one dimension, nanowires and nanotubes in two dimensions, and quantum dots in three dimensions. Nanoparticles have a significantly larger surface area per unit mass compared to larger particles due to their small size. Additionally, quantum effects are more pronounced at the nanoscale.

- Applications: Dental diagnostics, Preventive dentistry, Prosthodontics, Endodontics, Conservative and aesthetic dentistry and Dental root implant:

Tissue Engineering and Regenerative Dentistry

Quantum dots (QDs) have diverse applications in tissue engineering and regenerative dentistry. They enhance bone formation and cartilage regeneration, improve wound healing and scar-free tissue formation, and facilitate nerve repair. In dental tissue regeneration, QDs promote the differentiation of dental pulp cells into odontoblasts and can be integrated into dental restorations for enhanced properties such as hydrophobicity, antibacterial activity, biocompatibility, and self-cleaning. Graphene oxide quantum dots (GOQDs) are also valuable in dental tissue engineering by promoting the proliferation and differentiation of stem cells through the Wnt/β-catenin signaling pathway. Overall, QDs offer promising prospects for dental regenerative medicine.

Quantum dots (QDs) stimulating tissue growth and enhancing healing processes in oral surgery

Quantum dots (QDs) in oral surgery stimulate tissue growth and enhance healing processes. QDs promote tissue regeneration, possess antibacterial effects, enhance angiogenesis, modulate the immune response, and expedite wound closure. Their incorporation into scaffolds or hydrogels creates an optimal environment for tissue growth. QDs disrupt microbial cell walls, generate reactive oxygen species, and inhibit bacterial proliferation, preventing infections. They promote angiogenesis, improving blood circulation and accelerating healing. QDs modulate the immune response and inflammation through immunomodulatory pathways. In vivo studies demonstrate their positive effects on wound closure and tissue regeneration. QDs offer promising applications for oral surgical healing.

Fundamentals of Quantum Dots

Quantum dots (QDs) are tiny semiconductor particles, typically ranging from 1 to 10 nanometers in diameter. Their unique optical and electronic properties arise from quantum confinement, which confines electrons and holes within a small volume. By adjusting their size, the emission of specific wavelengths can be controlled. Smaller QDs emit shorter wavelengths such as blue and green, while larger ones emit longer wavelengths like yellow, orange, and red.

QDs offer notable attributes:

- High quantum yield
- Exceptional photostability
- High molar extinction coefficients
- Narrow and symmetrical emission spectra
- Adjustable optical features based on size
- Zero-dimensional structure with sharper density.

These features make QDs appealing for applications in bioimaging, solar cells, LEDs, diode lasers, transistors, and displays. QDs outperform traditional organic dyes, providing brighter and longer-lasting fluorescence.

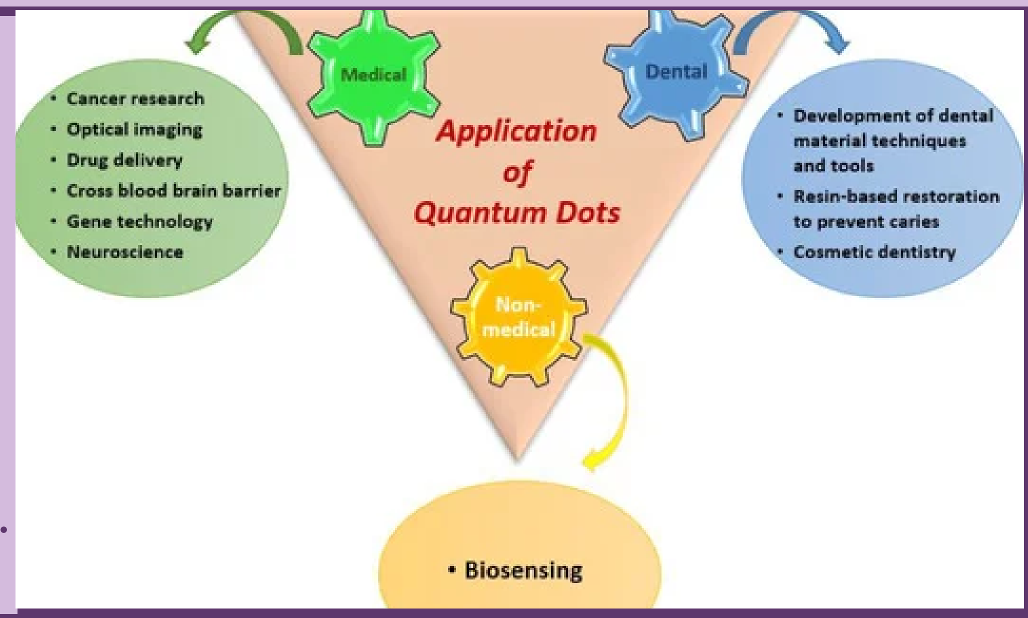
(a) Diagram representing the composition of a CdSe/ZnS quantum dot showing the core, shell, coating, and targeting molecules.
(b) Micromolar aqueous solutions of 525, 565, 585, 605, and 655 quantum dots under ultraviolet (UV) illumination

quantum dots differ from conventional materials in dentistry?

Quantum dots (QDs), nanoscale semiconductor particles, differ from conventional materials in dentistry by offering unique optical and electronic properties. In dentistry, QDs have various applications including diagnostic imaging, oral cancer treatment, and drug delivery. Unlike conventional materials, QDs can be coated with specific substances to enhance their binding to cancer cells. When activated by light, QDs emit light, enabling diagnostic imaging and therapeutic interventions. They also function as nanocarriers for drug or gene delivery in therapeutic treatments. QDs' exceptional optical properties make them highly attractive for dental applications, promising significant advancements in the field.

Importance of QDs in advancing dental technology

1. Enhanced Diagnosis and Imaging.
2. Tailored Medicine.
3. Real-time Surgical Guidance.
4. Early Disease Detection.
5. Accelerated Wound Healing.



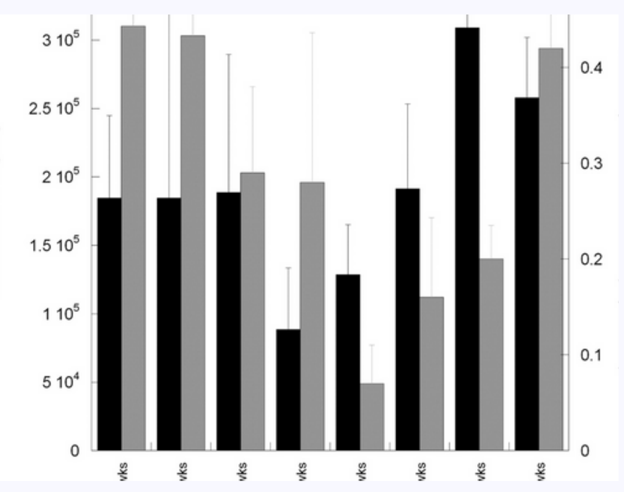
Incorporating quantum dots into drug delivery systems for dental therapeutics

Quantum dots (QDs), particularly carbon quantum dots (CQDs), have gained attention for their exceptional properties in drug delivery. CQDs possess fluorescence emission, small size for cell membrane permeability, low toxicity, chemical inertness, water solubility, and ease of synthesis. Researchers focus on encapsulating or attaching therapeutic agents, enhancing drug stability, solubility, and enabling targeted delivery and controlled release kinetics. Theranostic platforms integrating diagnostic and treatment capabilities using nanoparticle-based agents have also gained significant attention. Graphene quantum dots (GQDs) enhance the anticancer activity of drugs and show potential in Alzheimer's disease research. Glycine-proline-glutamate-conjugated GQDs (GQDGs) promote the growth of neuronal precursor cells and neurons, offering promise in combating neurodegenerative diseases. Quantum dot (QD) probes have been utilized for in vivo tumor targeting, both passively and actively, and hold potential in photodynamic therapy (PDT) by acting as photosensitizers and inducing targeted cellular destruction.

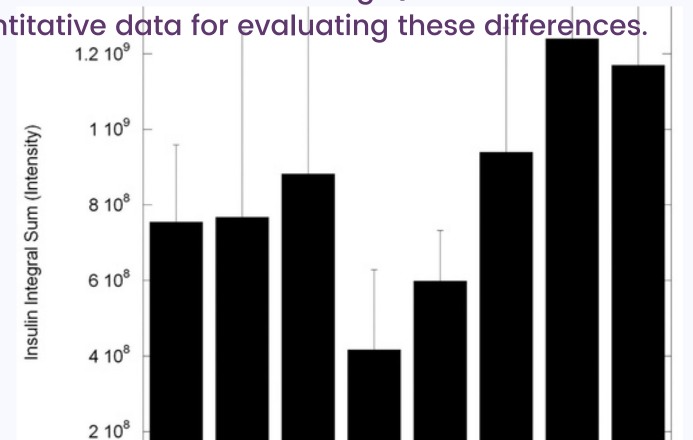
Quantum dots Applications In Dental Imaging

Fluorescent quantum dots (QDs) have gained attention for their unique optical properties, serving as valuable tools for imaging cells and tissues. Recent development focuses on conjugated QDs for in vitro and in vivo imaging. In vitro studies use QDs to label cells, such as acid-capped CdSe/ZnS QDs for labeling Hela cells.

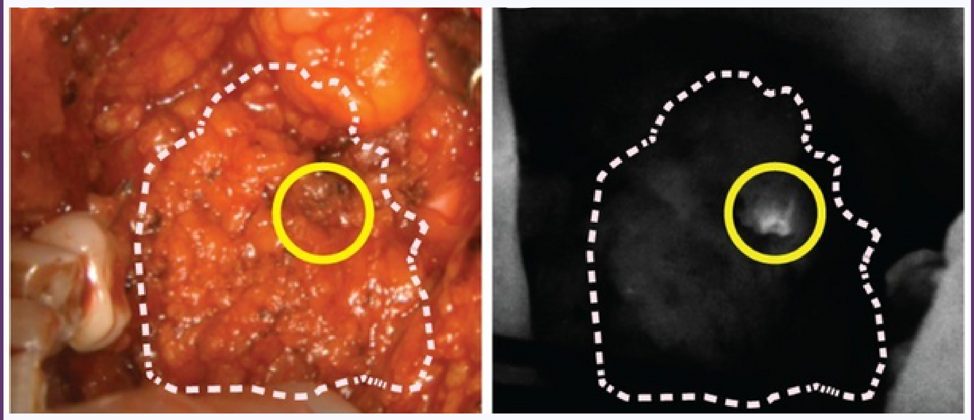
study quantified Qdot®-labeled sections in insulin, glucagon, and somatostatin markers in ZDF lean/Crl-Lepr+/+ and ZDF obese diabetic/Crl-Leprfa rats at different ages using laser scanning cytometry (LSC). QDs offer promising applications in cellular and tissue imaging.



The insulin labeling intensity, expressed in pixel intensity units, was measured using 525 nm Qdots® and LSC. In ZDF lean rats, the insulin labeling intensity per unit area varied but was generally higher compared to ZDF obese diabetic rats. In ZDF obese diabetic rats, the insulin labeling intensity per unit area was relatively low but showed an increase at 17 weeks of age. These findings indicate that there are differences in the characteristics of insulin labeling between ZDF lean and ZDF obese diabetic rats, both in terms of labeling area and intensity. The LSC measurements using Qdot® fluorescence provide quantitative data for evaluating these differences.



In Dentistry, real-time fluorescence imaging assisted in Head and Neck Cancer surgery. This study evaluated its clinical utility for intraoperative decision-making. It identified a secondary lesion outside the planned incision, prompting the surgeon to extend the incision based on the correlated fluorescence signal.



Nanotechnology enhances photoacoustic imaging (PAI) in dentistry, combining optical imaging and ultrasound. Advantages of nanoparticle (NP) utilization include stable and non-photobleaching fluorescent NPs as alternatives to dyes, nanotechnology-based immunotherapy for tumor inhibition, highly sensitive detection of early-stage carious lesions, and comprehensive visualization of tooth structure through multispectral near-infrared (NIR) imaging. These advancements in PAI, facilitated by nanotechnology, improve dental diagnostics and treatment planning.

Quantum dots (QDs) possess remarkable antimicrobial activity due to their unique properties, including photoluminescence and high structural stability. They can be functionalized with polymers like poly(ethylene glycol), polyethyleneimine, and poly-l-lysine, as well as conjugated with polymers such as poly(vinylpyrrolidone) and polyvinylidene fluoride to create antimicrobial membranes. These modifications enhance their antimicrobial efficiency and expand their applicability against multi-drug-resistant bacteria and fungi.

QDs exhibit diverse antimicrobial mechanisms, including the induction of free radicals, disruption of cell walls/membranes, and inhibition of gene expression. This multi-faceted approach sets them apart from traditional antibiotics. Despite their potent antimicrobial effects, QDs have relatively low toxicity to animal cells, making them a promising alternative in various research applications.

Graphene quantum dots (GQDs) in different structural dimensions can attach to microbial biomolecular lattices, inducing membrane stress and increasing oxidative stress. This leads to cell barrier damage, leakage of cell contents, and eventual cell death. Polymer-modified GQDs further enhance antibacterial activity by improving attachment to bacterial cell membranes. GQD-coated PVDF layers demonstrate superior antimicrobial activity compared to other carbon nanotube-modified membranes, thanks to the strong interaction between GQDs and thiol groups in cell membranes, triggering oxidative stress and effectively inhibiting microbial growth and biofouling.

Carbon quantum dots (CDots) are a new class of visible/natural light-activated antimicrobial agents that can effectively inhibit various microorganisms, including multidrug-resistant bacteria. CDots generate reactive oxygen species (ROS) upon photoexcitation, causing oxidative damage to the bacterial cell wall, membrane, and intracellular biomolecules, leading to cell death. CDots can be modified to enhance their antibacterial activity and selectivity, such as through functionalization with antibiotics like ampicillin or penicillin to selectively inhibit specific types of bacteria. They can also be incorporated into various materials, including hydrogels and nanocomposites, to develop antibacterial surfaces or wound dressings. CDots hold great potential as a versatile platform for antibacterial applications.