Review Article

Nanoparticles in Dentistry - An Updated Review

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Abstract

Nanoparticles having a size from 1 nm to 100 nm are present in nature and are successfully used in many products of daily life. In dental materials, nanoparticles are typically embedded but they may also exist as by-products from milling processes. Possible adverse effects of nanoparticles have gained increased interest, with the lungs being the main target organ. Exposure to nanoparticles in the dental laboratory is addressed by legal regulations. In dental practice, nanoparticles are mainly produced by intra-oral grinding/polishing and removal of materials, by wear of restorations or release from dental implants. Based on worst-case mass-based calculations, the additional risk as a result of exposure to nanoparticles is considered to be low. However, more research is needed, especially on vulnerable groups (patients with asthma or chronic obstructive pulmonary disease). An assessment of risks for the environment is not possible because of lack of data. Exposure-reduction measures mainly include avoidance of abrasive processes (e.g., by proper sculpturing), cooling by the use of water spray, and sufficient ventilation of treatment areas.

Keywords: Dentistry, nanomedicine, nanotechnology

Introduction

Nanomedicine is the controlled use of nanotechnologies/ nanoparticles in healthcare, leading to new pathways for the diagnosis and treatment of human diseases.[1] Nanoparticles are present in nature and are used in daily life; for example, in cosmetic products, such as sun screens (in which titanium dioxide [TiO_2] or zinc oxide [ZnO] particles are added as ultraviolet light filters), or in toothpastes, in dietary supplements and in sprays used for coating, cleaning and impregnation.[2] Silicon dioxide (SiO_2), magnesium oxide (MgO) and $TiO_2$are tested and licensed food additives in some countries.[3] Altogether, use of nanotechnology has great potential for improving daily life.

In dentistry, nanoparticles are intentionally embedded into products to improve material properties.[4] Dental materials that intentionally release nanoparticles are rare; such materials include scanning spray for computer-aided design/ computer-aided manufacturing[5] or occlusion indicator foils. On The other hand, nanoparticles can be nonintentional by-products from milling processes for fillers. It has been estimated that nanoparticles are present in about 3,500 dental materials. The aim of this brief survey is to provide some basic information for the dental community on nanoparticles. The original text for this review has been published recently else-where;[6] here, we provide a shortened version.

According to the European Union (EU), nanoparticles have one or more external dimensions in the size range from 1 nm to 100 nm.[7] More detailed definitions are provided by the International Organization for Standardization.[8,9] Nano-sized single particles may, however, arise readily to form clusters, namely aggregates (strongly bonded) and agglomerates (weakly bonded).[8] The definition of a nanomaterial (e.g., by the EU7) is presently under discussion and may be changed; therefore, in this review only the term nanoparticle is used.

Nanoparticles in and from Dental Materials

Resin-based composites contain inorganic filler particles of different sizes, ranging from supra-micron to sub-micron and nano-sized.[10] Today, mainly radio-opaque glass-fillers containing, or example, barium, zirconium, strontium or ytterbium with a size between 400 nm and 1lm, or even larger,

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are used together with nano-sized particles such as pyrogenic silica (SiO2) or zirconium dioxide (ZrO2)-SiO2.[11] The filler particles are embedded in the resin matrix and chemically attached to it through silane coupling.

Zinc phosphate cements contain ZnO or MgO particles in the powder, glass ionomer cements contain finely ground glass particles and some products may contain pyrogenic silica as nanofillers. Hydraulic calcium silicate cements contain different calcium silicates and aluminates[12] and impression materials contain a variety of fillers (e.g., ZnO or TiO2). Filler size is normally in the micrometer range, but nanoparticles can be unintentional by-products of the milling process. The above-mentioned materials are delivered as premixed pastes which are cured by light activation within 1 min or as paste/paste or powder/liquid systems, which have to be mixed and which set in <5 min.[13-15] Nanoparticles on implants are strongly bound ('fixed') to the surface of the implant 10 to prevent infection (e.g., silver nanoparticles) or to improve biocompatibility (e.g., apatite or titanium [Ti] parti-cles23). Furthermore, pigments in the form of nanoparticles are used. When grinding resin materials, nanoparticles containing substances of unknown com-position derived from the resinous matrix through heat generation[16] may be produced.

Ti nanoparticles from Dental Implants

Titanium is one of the most biocompatible metallic materials as a result of its ability to form a stable and insoluble protective oxide layer (TiO2) on its surface.[17] Ti is preferentially used for endosseous dental implants and the properties of Ti implants can be improved by using nanostructured Ti-containing particles or Ti nanoparticles (Ti-NPs).[18-20] However, a recent vitro study[21-23] demonstrated a size-dependent cytotoxicity and DNA damage of Ti particles. Genotoxic Effects of Ti particles have also been detected, such as induction of apoptosis in mesenchymal stem cells.[24] It Was claimed that peri-implantitis can arise by exposure to TiO2, even in the absence of bacteria.[25] Furthermore, a previous post mortem study investigating metal particles released from implants showed bone marrow fibrosis. In a clinical study, 0.6% of 1,500 patients were found to exhibit allergic reactions to Ti.[26] The highest Ti content detected in human mandibular bone was 37,700 lg/kg of bone 38. Assuming that all Ti in the bone is Ti-NPs and that 1 kg bone equals 1 l of fluid, a Ti-NPs concentration of 37lg/ml can be calculated. The half-maximal effective concentration (EC50) for Ti nanoparticle inhuman cells is 2,800 lg/ml.[27] Therefore, it is assumed that Ti-NPs released from dental implants might have no toxicologically clinical effects.

Silver Nanoparticles

Heinlaan *et al*. described that AgNP s were very toxic to Daphnia Magna (Organisation for Economic Co-operation and Development [OECD] 202) (48-hour EC50: 1–5.5lg of Ag/l), as well as to Danio rerio (OECD 236) (96-h EC50: 8.8–61lg of Ag/l), embryos.[28] These values are 10-100 times lower than the Ag (nano) particle concentrations measured after release from metallic implant coatings. There are also clinical problems associated with AgNPs, such as color change (or impairment of the polymerization process of resin-based materials, which then leads to increased release of substances (e.g., monomers.[29] The Actual risk of the inclusion of AgNPs into resin-based composites is presently difficult to estimate. However, the potential of adverse biological effects of resin-based composites when adding AgNPs seems to be increased.

Risk for The Environment

It can be assumed that particles from resin-based composites reach the environment and that included residual monomers will be released. However, in the 2014EU report (Scientific Committee on Health and Environmental Risks)[30] it is stated that the information available on the mercury (Hg)-free alter-natives to amalgam does not allow a sound risk assessment for the environment to be performed.

Conclusion

Available data on possible adverse reactions derived from nanoparticles in dental materials or by processing dental materials dealing with additional particle-related risks are sparse and more research is necessary. In the dental laboratory, technicians are exposed to nanoparticles as dust and must follow available relevant national/international safety regulations. In dental practice, virtually no exposure to nanoparticles occurs when handling unset materials. Dental personnel are mainly exposed to nanoparticle dust produced by grinding/polishing set dental materials, irrespective of the presence of nanoparticles in the material and the lungs are the prime target organ.

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Conflicts of interest

There are no conflicts of interest.

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