Nano–bio interactions

Nanomaterials (NMs) and technology is the present research theme in prosthodontics. The small-sized nanoparticles have distinct properties that enable to use in wider applications. An increased number of in vitro studies have been done in nano-prosthodontics that produced significant results, and progressive research has been attained.[1,2] Although significant advantages exist in nanoresearch, investigation lacks in the dimension of biological interaction. The cellular absorption, intercellular pathways, mechanisms of action, toxicity, and bio-interactions with tissues and organs have not been extensively studied, and this limits its clinical usage.[3]

The unique characteristics of NM including higher percentage of surface atoms, surface energy, decreased particle size, variations in crystal boundary, and decreased molecular density improve the optical, mechanical, magnetic, and thermal properties of the material. The high surface energy leads to improved reactivity and ease in merging with the other atoms, can be both advantageous and disadvantageous. The increased reactivity with cellular components can lead to various adverse reactions. The understanding of absorption mechanism can aid in better designing of the NM.[3]

NMs unlike macro-materials are small in size, highly interactive, can directly penetrate cells, and can interact with intercellular components. The cellular absorption of nanoparticles is through the pinocytosis; macropinocytosis; clathrin-mediated, caveolae-mediated, and lipid raft-mediated endocytosis; and phagocytosis.[3,4] Endocytosis is the most common mechanism of cellular infiltration. The NMs entering the cells are locked in endosomes, transported to lysosomes, and moved out of cells. In situations, the NMs can move out of endosomes and penetrate cytosol, mitochondrion, nucleus, and other organelles.[3] The absorption and intercellular trafficking are greatly connected to their shape, size, surface charge, and surface modification of NM. These interchanges and transfers are essentially to be monitored for the adverse effects of NM. The production of reactive oxidative species (ROS) is common toxic effect of NM. ROS can interact and damage the intercellular components. The additional effects of decreased cell growth, arrest of cell development, inflammation, chromosome aberration, and damage to DNA strands were reported in the literature.[3]

The effect between nanoparticles at the cellular system is of great concern. The outcome depends on surface charge, physical factors, stability of NM, viability, physiology, and trafficking in cells. The controlled size and shape of NM have an improved effect than irregular-shaped particles in majority of studies. Besides the size, the surface functional groups of NM also determine its effects and cellular penetration. Positively charged units are better absorbed by cells than negatively charged units, and the hydrophilic materials have better penetration than phobic materials. The ease of cell penetration is useful in drug delivery and therapeutic applications. In addition, the vascular dynamics and effortless cell penetration of smaller NM can generate toxic products through protein unfolding, fibrillation, thiol cross-linking, and loss of enzymatic activity.[3] The evaluation of transformation and NMs’ surface chemistry in living creatures is complicated. In the cellular environment, multiple interactions occurs between the NM and the amino acids, peptides, and proteins. The reactions of cellular components determine the transportation, reaction, therapeutic effect, toxicity, and exclusion of the particles.[3] Various studies have examined the relationships between NM and cells, but still a lot has to be investigated. The factors on the properties of materials, cell lines, in vitro estimations, and methodical studies on specific materials are poorly understood, and these studies have to be improved, standardized, and evaluated.[3,4]

The use of new NM has to be done with caution. Many materials lack the datasheet on toxicity, tissue interactions, and its risk effects on human health. The NM toxicity has to be evaluated through a series of fundamental toxicity tests such as oral toxicity, dermal irritation, eye irritation tests, genetic assessments, and lung instillation studies. The data on oxidative stress, immune response, cytotoxicity inflammation, genotoxicity, and potential fibrogenicity have to be generated for its potential use in biological system.[3,5–7]
The material information on its effects on cardiovascular, pulmonary, hepatic, renal, and developmental systems has to be obtained before its clinical use.

The risks of using NM are evaluated through sequence of procedures during their development. It involves assessment of material characterization for size, shape, surface charge, evaluation of hazards and risks of exposures of NM, measurement of risks, and exposure and finally it has to be documented with future reviews.[7] The NM toxicity and the bio-safety of materials have not been clearly identified and require investigations. With the evolutions of materials and evaluation technology, the understanding of these parameters becomes better and more appreciable. The knowledge on bio-interactions of NM can aid in improved development of biomedical applications.

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