Chapter 5
Applications of Polymeric Micro- and Nano-Particles in Dentistry

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ABSTRACT

The use of micro- and nanoparticles is rapidly advancing and has been most commonly used in medical and biological research that offers an encouraging scope in broad range of disciplines. Manipulation of the biomaterials to their micro- and nano-scale renders their properties and behavior different from that of the same material in the mass scale and make them more reactive than large particles. The removal of tooth structure and its restoration with synthetic material to solve the problems caused by dental caries, trauma and fracture is a practice nearly as old as dentistry. Efforts are made to create micro- and nanomaterials that can revolutionize these ancestral therapies and dental procedures. The use of these materials had shown some promising applications in caries control, endodontic therapy, regenerative dentistry, periodontology and oral biofilm management. This review aims to discuss the recent advances and future potential of polymer-based micro- and nanoparticles in dentistry.

INTRODUCTION

The prevention of tooth decay, treatment of bone loss and periodontal disease are ongoing challenges in dentistry. According to CDC, tooth decay is the most frequent childhood disease 5 times as common as asthma. LA Times came up with the fact that 42% of children are expected to have some decay by the age of 2-12 (Mascarelli, 2011). For example, in 2015-16, a UK report shows that 9.8% rise in removal of one or more teeth in children aged 10 and under (Howell, 2016). Periodontal diseases are the most

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common infections due to the overgrowth of the dental plaque that may increase the risk of heart disease and it is estimated that 47.2% of adults aged 30 years and older has some form of periodontal disease (Dhadse, Gattani, & Mishra, 2010).

With the emergence and increase of such dental problems and continuing concerns on healthcare costs, many researchers have tried to develop new and effective treatment regimes. Such problems and needs have led to the resurgence in the use of micro- and nanomaterials in order to revolutionize the ancestral therapies and dental procedures. For example, liquids and pastes containing nano-apatite's have been used remineralization of early sub micrometer sized enamel lesions and the role of nanoparticle in the control of the oral biofilm has also been recognized (Figure 1) (Besinis, De Peralta, Tredwin, & Handy, 2015; Hannig & Hannig, 2010). Similarly, micro-/nanoparticles that can deliver antibiotics and bioactive compounds have been used to treat periodontal diseases (Yao et al., 2014).

Application of micro-/nanotechnology in dentistry aims at using these materials and theories to enhance prevention, diagnosis and treatment of injured tissues at the molecular and micro molecular levels. The high surface area to volume ratio of these materials has reportedly shown to improve the biomaterial-biological interactions (Yong, 2014). Their ability to penetrate inside locations that are inaccessible make them best suited for various site-specific delivery (Cristina Buzea & Kevin, 2007). Moreover, their stability during storage as well as in biological fluids makes them advantageous in many ways. The shape of these materials enhances their surface reactivity and renders high antibacterial action in comparison to other formulations (Khodashenas & Ghorbani). Although still evolving with their developments at infancy, these fields provide an array of possibilities that benefit the patient's health by eliminating or reducing pain associated with conventional procedures.

The use of polymeric micro-and nanoparticles has been the epicenter of extensive research in the recent years. Polymers are high performance materials predominantly used in controlled drug release due to their versatility and unique physical, chemical and structural properties that hold tremendous promise for improvements in many areas of scientific research. The use of polymers plays a major role in improving the mucoadhesive properties of nano and micro biomaterials because this improvises the interaction of polymeric particles with biological systems, especially tooth structures that are predominantly hard tissues, where it is difficult for particles to adhere. For example, both natural (e.g., chitosan and alginate) and synthetic (e.g., poly(lactic-co-glycolic acid) and poly(ε-caprolactone)) polymers have been used as carrier materials, that can be either biodegradable (e.g., poly(lactic-co-glycolic acid) or non-biodegradable (e.g., ethylcellulose) based on their ability to breakdown in a given environment.

Polymer nano and microparticles are most commonly synthesized by various methods shown in Figure 2. Other innovative procedures like dripping technique, microfluidic systems and high pressure homogenization have also been used (de Francisco, Cerquetani, & Bruschi, 2012). The dramatic impact of these materials on medicine and biology has led to applications including coatings on medical devices, wound dressing materials, antimicrobial agents, drug or gene delivery systems and bio imaging (Ambrosio & Payne, 2013; Hutter & Maysinger, 2013; Rai, Yadav, & Gade, 2009; Tsukada, Goan, & Furusawa, 2008; S. Z. Wu, Hossainy, Harish, Sanders-Millare, & Mirzaee, 2003; Zheng, Chen, Jin, Ye, & Liu, 2016). With such convincing developments in technology, micro-and nanoparticles have been anticipated to bring advances (Figure 3) and possible innovations in existing oral diagnostic and therapeutic techniques (Ozak & Ozkan, 2013). Some of the clinical aspects mentioned above (e.g., antibacterial, drug delivery) find relevance in the field of dentistry and has received significant momentum in the past few years. In this book chapter, we will mainly focus on the applications of polymer micro- and nanoparticles in dentistry.

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