Review Article

Recent Applications of Nanomaterials in Prosthodontics

Wei Wang,¹ Susan Liao,² Yuhe Zhu,¹ Ming Liu,¹ Qian Zhao,¹ and Yating Fu¹

¹*Department of Prosthodontics, School of Stomatology, China Medical University, Shenyang 110002, China*

²*School of Materials Science and Engineering, Nanyang Technological University, Singapore 639798*

Correspondence should be addressed to Wei Wang; yuhe740442@hotmail.com

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In recent years, lots of researches have been launched on nanomaterials for biomedical applications. It has been shown that the performances of many biomaterials used in prosthodontics have been significantly enhanced after their scales were reduced by nanotechnology, from micron-size into nanosize. On the other hand, many nanocomposites composed of nanomaterials and traditional metals, ceramics, resin, or other matrix materials have been widely used in prosthodontics because their properties, such as modulus elasticity, surface hardness, polymerization shrinkage, and filler loading, were significantly increased after the addition of the nanomaterials. In this paper, the latest research progress on the applications of nanometals, nanoceramic materials, nanoresin materials, and other nanomaterials in prosthodontics was reviewed, which not only gives a detailed description of the new related investigations, but also hopefully provides important elicitation for future researches in this field.

1. Introduction

Prosthodontics is an important branch of the oral medicine. With the improvement of people's living standards and the promotion of oral health knowledge, prosthodontics increasingly received widespread attention. Prosthodontics is mainly for dental defects, treatment after tooth loss, such as lays, crowns, and dentures, also including the use of artificial prostheses for periodontal disease, temporomandibular joint disease, and maxillofacial tissue defects [1–4]. The main purposes of dentures are to restore dental function and facial appearance and maintain the wearer's health. Dental materials of dentures can be divided into mainly three categories: resin, ceramic, and metal. They are important to fabricate dental prosthesis, which directly contacts with the oral mucosa and is under long-term use in the oral environment, so the dental materials must have comprehensive properties and good biological activity to function properly. Dental materials should have certain mechanical strength, hardness, higher fatigue strength, high elastic modulus, low thermal and electrical conductivity, good castability, and less shrinkage deformation. Chemical stability is also required, such as corrosion resistance, being not easily broken, and aging. The colors of dental materials can be formulated and

maintain long-term stability. As a good oral material, it should have good biocompatibility and safety and be biofunctional [2–4]. However, due to the nature of the material itself, continued use for long period in moist environment, a variety of problems will occur during wear dentures, such as pigment adhesion, color change, and aging fracture.

In recent years, nanomaterials have captured more and more attention because of their unique structures and properties. The concept of “nanomaterials” formed in the early 1980s, referring to zero-dimensional, one-dimensional, two-dimensional, and three-dimensional materials with a size of less than 100 nm [5, 6]. Nanomaterials can be divided into four categories of nanopowder, nanofiber, nanomembrane, and nanoblock, in which development of nanopowder is longest, and its technology is most mature [6]. Nanomaterials have small size, large surface area, high surface energy, a large proportion of surface atoms, and four unique effects: small size effect, quantum size effect, quantum tunneling effect, and surface effect [7]. Development of nanomaterials has greatly enriched the field of research in materials science including biomaterials. As people understanding of natural biological material properties and microstructure at nanoscale is gradually deepening, the role of nanomaterials in biomedical material science is more important [7, 8]. Studies showed that

FIGURE 1: Hierarchical structure of the dental enamel. The enamel is composed of three-dimensionally organized nanosized hydroxyl apatite crystallites. (a) Atomic force microscope, (b) scanning electron microscope images of the enamel surface, and (c) transmission electron microscope [9].

a natural tooth is biological nanomaterial, which is composed of enamel, dentin, and cementum with nanoscale particles.

Dental enamel comprises 80–90% volume of calcium-deficient carbonate hydroxyl apatite. Mature-human-enamel crystallites are 26.3 ± 2.2 nm thick, 68.3 ± 13.4 nm wide, and between 100 and 1,000 nm long (Figure 1) [9, 10]. Dentine is a hydrated tissue made up of approximately 50 vol.% mineral, 30 vol.% collagenous and noncollagenous proteins, and 20 vol.% fluids. The dentinal matrix is mainly composed of type I collagen fibrils forming a three-dimensional scaffold matrix, reinforced by hydroxyl apatite crystallites, measuring approximately 20 nm in size [11, 12]. This natural dental hard tissue structure provides a foundation platform for biological research of nanomaterials with biomimetic manners.

Nanomaterials have been developed promptly and some researches of nanomaterials have been carried out on prosthodontics. Many of the current dental materials are available through nanocrystallization to improve their original performance and play continuously key role in oral applications. Research of nanotechnology in dental materials is mainly focused on two ways: one is the preparation of new inorganic nanoparticles, and the other is to modify the surface with inorganic nanofillers and thereby to develop ultralow shrinkage rate of repair resin [13]. Through the development of nanocomposites, properties such as modulus

of elasticity, surface hardness, polymerization shrinkage, and filler loading were enhanced by the addition of nanomaterials [14, 15]. Nanocomposite denture base has higher interfacial shear bond strength between the resin matrix and nanomaterials, compared to the conventional resin matrix. It is because that this supermolecular bonding covers or shields the nanomaterials and creates thick interface, which enhances the bond between the resin molecules and creates higher molecular weight polymers [16]. Nanomaterials are mainly used in ceramic, resin, and metal, providing a huge space for the improvement and innovation of dental material. Nanoceramic material has small grain size and the inherent porosity of materials greatly reduced, on one hand improving the flexibility, strength, and plasticity and on the other hand making its elastic modulus similar to natural bone, greatly improving the mechanical compatibility and biocompatibility [15–17]. The emergence of nanoresin may change the nature of the resin that is easy to be aging and increase its strength [16–19]. Studies of nanometal showed that it might have better antibacterial property [20].

In this paper, we briefly reviewed the development history of prosthodontics materials including metals, ceramics, and resin and evaluated the research and application of nanomaterials in prosthodontics. The properties of those prosthodontic materials were summarized in Table 1.

TABLE 1: Properties of prosthodontics materials.

Dental materials	PMMA	Ceramics			Metal		
		ZrO ₂	Al ₂ O ₃	glass ceramic	Ti6Al4V	CoCrMo	CoCr
Advantage	Good biocompatibility, aesthetics processability, and reparability [3]	High strength, suitable color, and low thermal and electrical conductivity [21]			Titanium alloy has high strength, low density, light weight, low shrinkage, nonmagnetic, good mechanical properties and corrosion resistance, and nonallergic, teratogenic, and carcinogenic. CoCr alloy has high strength, wear resistance, and less tooth tissue cutting, with good biological safety CoCrMo has good corrosion resistance, wear resistance, ductility, gloss, anti-plaque adhesion and biosafety		
Disadvantage	Poor strength, low fracture resistance radiopacity behavior, and microbial adhesion [2, 4, 18, 20]	Low ductility and brittleness [21]			Further improvement is desired to improve the corrosion resistance and biocompatibility of the Ti and CoCrMo alloy CoCr alloy easily leads to sensitive symptoms		
Nanoresearch	TiO ₂ nanoparticle reinforced the mechanical behavior of PMMA [17] Well-dispersion nano-ZrO ₂ particles can improve the modulus and strength and maintain or even improve ductility [17] Ag TiO ₂ and Fe ₂ O ₃ particles significantly reduce adherence of <i>C. albicans</i> of PMMA and do not affect metabolism or proliferation [22–24]	The hardness and fracture toughness increased of nanozirconia ceramics [25] Glass ceramics with nanosized grains showed excellent corrosion resistance, high fracture toughness, and translucency [26]			Nanophase metals (specifically, Ti, Ti6Al4V, and CoCrMo alloys) promote osteoblast adhesion, proliferation, differentiation, and mineralization [27–29]		

2. Nanomaterials Applied in Prosthodontics

2.1. Nanometal Materials in Prosthodontics. Currently, most metal stents of partial denture are applying cobalt-chromium alloy or cobalt-chromium-molybdenum alloy and titanium alloy [27–29]. The initial cobalt-based alloy is cobalt-chromium binary alloy and is then developed into cobalt-chromium-tungsten alloy and later developed into cobalt-chromium-molybdenum alloy [27]. Its mechanical properties and corrosion resistance are better than stainless steel or gold alloy [28, 29]. Another metal material that is often used in prosthodontics is titanium alloys because of its outstanding properties which are close to natural human bones, such as high specific strength, good biological security, high corrosion resistance, and elastic modulus. Although those metal prosthodontics materials have excellent mechanical properties, less tooth tissue cutting, and good biological security, biological integration is usually unsatisfactory, and some patients are prone to allergies, causing skin, mucous membrane inflammation [22, 30, 31]. Satisfactory biological integration of the implant surfaces with the surrounding host tissues is one of the most important elements for long-term success of dental implants. Modification of titanium implant surfaces into nanostructures has been found to be able to improve their biological integration with surrounding

soft tissues. Dorkhan et al. modified the surface of titanium implant by anodic oxidation into nanoscales with pores in the 50 nm range and found that both the vitality and the adherence level of soft-tissue cells, such as keratinocytes and fibroblasts, on the nanostructured surfaces were similar to those on pure titanium, while the attachment of oral streptococci on the nanostructured surfaces was significantly lower than on the pure titanium [32, 33], suggesting that the nanostructured surfaces of metal implants might be capable of improving surrounding host tissue cell adherence while minimizing bacterial attachment.

Another nonnegligible disadvantage for titanium alloy as oral implant material is its relatively poor wear resistance. To overcome the drawback, nanostructured ceramic coatings such as TiN, ZrO₂/Al₂O₃, Si₃N₄/TiO₂, and ZrO₂/SiO₂ are being used [23, 24, 34–37]. Sathish et al. coated a novel nanostructured bilayered ZrO₂/Al₂O₃-13TiO₂ on biomedical Ti-13Nb-13Zr alloy. The bilayered coating was shown to exhibit 200- and 500-fold increase in the wear resistance, compared to the monolayer Al₂O₃-13TiO₂ and ZrO₂, respectively, because of its higher adhesion strength and lower porosity [38]. Many studies have demonstrated increased functions of osteoblasts on nanophase compared to conventional materials such as ceramics, polymers, carbon nanofibers or nanotubes, and their composites. For example, Li et al. investigated

the functions of human adipose-derived stem cells cultured on carbon nanotubes, compared to those of the cells cultured on microstructured graphite that have the same composition and layered structure with carbon nanotubes. The cells attached and proliferated better on carbon nanotubes. Moreover, the cells synthesized more alkaline phosphatase and deposited more extracellular calcium on carbon nanotubes [39]. So whether nanometal possesses better biological activity than traditional metal attracted researchers' attention. At present, many studies have shown that titanium and titanium alloy with nanosizes have better biocompatibility than traditional titanium and titanium alloy. Researchers have fabricated metal surface nanocrystallization by different methods for improving biological activity of the metal. Lan et al. [40] prepared a nanotextured titanium surface using a chemical etching technique and studied the effects of a nanotextured titanium surface on murine preosteoblastic cells adherence, proliferation, differentiation, and mineralization *in vitro*, setting rough and smooth surfaces of pure titanium as controls. A characteristic nanotexture was formed on the titanium surface according to the result of SEM. The number of cells attached to the nanotextured titanium surface was higher than that of the cells attached to smooth surfaces of pure titanium after the incubation of 30, 60, and 120 minutes, respectively. Under SEM for the nanotextured surface, more adherent cells and larger spreading areas were observed. The proliferation of cells, after 3 and 5 days, was significantly higher on the nanotextured surface than controls according to the results of CCK-8 test. The alkaline phosphatase activity of the cells on the nanotextured titanium surface was higher at 7 days than 3 and 5 days. In addition, a larger amount of calcified nodules could be observed on the nanotextured titanium surface 14 days later. The results above suggest that it should be better to further consider nanotechnologies for prosthodontic implant applications.

Yao et al. [41] created nanometer surface features on titanium and Ti6Al4V implants by anodization, which was a quick and relatively inexpensive electrochemical method. The results showed that the anodized surfaces had higher root-mean-square roughness at nanoscale dimensions than the unanodized Ti-based surfaces. Most important of all, as compared to respective unanodized counterparts, osteoblast adhesion was enhanced on the anodized metal substrates according to the results of *in vitro* studies. Thus, it demonstrated that anodization of Ti-based metals might create nanometer surface features that could promote osteoblast adhesion.

Webster and Eijofor further provided the evidence of increased osteoblast adhesion on Ti, Ti₆Al₄V, and CoCrMo compacts with nanometer compared to conventionally sized metals [20]. In their study, each respective group of nanophase and conventional metals possessed the same material properties (chemistry and shape) and altered only in dimension. Human osteoblasts were seeded and placed in standard cell culture conditions for either 1 or 3 h. As expected, the dimensions of nanometer surface features gave rise to larger amounts of interparticulate voids in nanophase Ti and Ti₆Al₄V. Osteoblast adhesion was significantly greater on nanophase Ti, Ti₆Al₄V, and CoCrMo

when compared to their conventional counterparts after 1 and 3 h and osteoblast adhesion occurred primarily at particle boundaries (Figure 2). Since nanophase materials possess increased particle boundaries at the surface (due to smaller particle size), this may be an explanation for the increased osteoblast adhesion measured on nanophase formulations. This study implies further enhanced adhesion of osteoblasts on nanophase Ti, Ti₆Al₄V, and CoCrMo. The result suggests that nanophase metals may be a kind of potential materials in prosthodontics or implant applications.

2.2. Nanoceramics Materials in Prosthodontics. Ceramics have been used in manufacture of dental dentures because of their high strength, suitable color, and low thermal and electrical conductivity [21]. At present, ceramic dental crown is mainly including alumina ceramic and zirconia ceramic. Traditional ceramics are made of clay and other natural occurring materials, while modern high-tech ceramics use silicon carbide, alumina, and zirconia. The development of ceramic crown experienced long essence of ceramic materials: hydroxyapatite (HA) ceramic, glass ceramic, alumina ceramic, and zirconia ceramic. Alumina ceramics have good aesthetics, high gloss, chemical stability, wear resistance, high hardness, good biocompatibility, no allergies, and no effect on the MRI, but the biggest drawback is crisp, and it is likely to porcelain crack [42]. ZrO₂ has a good abrasion resistance, physiological corrosion resistance, and biocompatibility, whose modulus of elasticity, flexural strength, and hardness are higher, compared to those of HA and titanium alloys. The strength and bending resistance of zirconia ceramics through computer aided design/computer aided manufacture are significantly higher than alumina ceramic, but they still lack toughness and high sintering temperature [43].

Because the low ductility and brittleness of ceramics directly influence and limit the development of the traditional ceramic materials, we hope that nanostructured ceramics may offer some specific improvements. In addition, dental applications of ceramic materials add aesthetic requirements (colour, translucency) to the mechanical specifications. Nanostructured ceramics may meet the need for translucency of dental restoration. Examples of transparent or highly translucent ceramics (alumina, YAG, etc.) are already published but not dedicated to the clinical application [44, 45]. Nanoceramic refers to the ceramic material with nanoscale dimensions in the microstructures phase. Compared with the conventional ceramics, nanoceramics have unique properties, which make it become the hot topics in the study of material science. Firstly, nanoceramics have superplasticity. Ceramic is essentially a kind of brittle material; however, nanoceramic shows good toughness and ductility. As far as the arrangement of atoms in nanoceramics interface is quite confusing, the atoms are very easy to migrate under the conditions of force deformation. Secondly, compared to the conventional ceramics, nanoceramic has the superior mechanical properties, such as strength and hardness increasing significantly. The hardness and strength of many nanoceramics are four to five times higher than those of the traditional materials. For example, at 100°C the microhardness of nano-TiO₂ ceramics is 13,000 kN/mm², while

FIGURE 2: SEM images of osteoblasts on Ti and $\text{Ti}_6\text{Al}_4\text{V}$ compacts, respectively [20].

that of ordinary TiO_2 ceramics is lower than $2,000 \text{ kN/mm}^2$. Most importantly, toughness of nanoceramics is much higher than that of traditional ceramics. At room temperature, nano- TiO_2 ceramic exhibits very high toughness. When compressed to 1/4 of the original length, it was still intact without being broken [46].

Li et al. reported the different physical properties of nano- ZrO_2 ceramic materials from the traditional ones. The hardness of traditional ZrO_2 was generally around 1,500, and its fracture toughness was very low, so breakage or crack might easily occur in the processing. However, the hardness of nanozirconia ceramics could reach more than 1,750, increased by about 20%. Not only does its hardness increase, but also the fracture toughness also increased accordingly [47]. Wang et al. reported the influence of nano- ZrO_2 content on the mechanical properties and microstructure of nano- ZrO_2 toughened Al_2O_3 and found that the composite had better toughness with 20% nano- ZrO_2 , very suitable as dental all-ceramic restoratives [25].

Glass ceramics based on lithium disilicate with lack of mechanical properties are commonly used in dental veneers and crowns. Due to insufficient mechanical properties of glass ceramics, failure clinical cases have been often reported. To improve mechanical properties of glass ceramics based on lithium disilicate, Persson et al. used a sol-gel method to produce glass ceramics in the zirconia-silica system with nanosized grains, which was found to be translucent, with a transmittance of over 70%, and possessed excellent corrosion resistance. It also presented a somewhat lower elastic

modulus but higher hardness than the conventional lithium disilicate [26].

Carbon nanotubes (CNTs) have attracted remarkable attention as reinforcements of materials because of their exceptional mechanical and electronic properties. Furthermore, CNTs have been considered as reinforcing elements in ceramic matrix composites due to their unique mechanical properties [48, 49]. An et al. produced alumina-CNT composites by hot-pressing and investigated the mechanical and tribological properties of alumina-CNT composites (Figure 3) [50]. The results showed that wear and mechanical properties were enhanced in the range of 0–4% CNT content and the addition of CNTs up to 4% has a positive influence on the reinforcement effect, increased about 30%.

2.3. Nanoresin Based Materials in Prosthodontics. Currently, resin used in prosthodontics is mainly including polymethyl methacrylate (PMMA) and its modified products. PMMA is obtained by the polymerization of acrylic acid and its esters and is dating back over one hundred years of history. In 1937, the methyl acid lipid began to enter scale manufacturing and was applied to the denture base processing. The wide range of clinical applications of PMMA was successfully developed by the Kulzer Company in Germany in 1930. The main component of PMMA is polymethyl methacrylate, also containing small amounts of ethylene glycol dimethacrylate [51]. PMMA has good mechanical properties such as high hardness, rigidity, discontinuity deformation, biological properties, aesthetic properties, and easy processing

FIGURE 3: The fractured surface morphologies of the hot-pressed alumina composites: (a) with 2.7 wt% CNT content, (b) with 4.1 wt% CNT content, and (c) with 12.5 wt% CNT content [50].

characteristics. Its main disadvantages are the instability of color, poor resistance to wear and tear, volume shrinkage after the polymerization, oral mucosa irritation, and aging, and staining or discoloration relatively easily occurs [3].

Nowadays, most products for dental restoration have been produced from acrylic resins based on heat-cured PMMA, due to its optical properties, biocompatibility, and aesthetics [52, 53]. However, it has a long-standing drawback that is lack of strength particularly under fatigue failure inside the mouth and also shows low abrasion resistance and microbial adhesion onto PMMA to long-term PMMA wearers. Therefore, some studies are still ongoing in order to solve these problems and improve acrylic polymers properties for artificial dentures [54]. Recently, much attention has been directed toward the incorporation of inorganic nanoparticles into PMMA to improve its properties. Various nanoparticles such as ZrO_2 , TiO_2 , and CNT have been used to improve the performance of PMMA, and the results showed that desired mechanical property enhancement can be achieved in those composites with small amounts of nanoparticles [16–19].

The mechanical behaviors of TiO_2 nanoparticle-reinforced resin-based dental composites were characterized in the paper of Hua et al., using a three-dimensional nano-scale representative volume element [16]. The results clearly showed that, to achieve the same reinforcing effect with microcomposites, nanocomposites needed much lower volume fraction of reinforcing media because nanoparticles with

aspect ratio larger than 30 could nearly make the reinforcing effect reach saturation. For example, the reinforcing effect of the nanoparticle with 3% volume fraction on the stiffness is the same as that of the glass fiber with 6% volume fraction. These results might provide us with valuable inspiration to optimize the compositions of dental composites. Mohammed and Mudhaffar [17] designed and evaluated the addition of modified ZrO_2 nanomaterials in different percentage (2 wt%, 3 wt%, and 5 wt%) to heat-cured acrylic resin PMMA materials. Abrasive wear resistance and tensile and fatigue strength showed highly significant increase with 3 wt% and 5 wt% of nanofillers, compared to pure PMMA materials. The same results were showed in the study of Hong et al. where methacryloxypropyltrimethoxysilane- (MPS-) modified colloidal silica nanoparticles were added to PMMA, which caused a significant increase in tensile strength and tensile modulus [18].

CNTs and carbon nanofibrils have been used as reinforcements or additives in various materials to improve the properties of the matrix materials. Cooper et al. prepared the composites consisting of different quantities of CNTs or carbon nanofibrils in a PMMA matrix using a dry powder mixing method (Figure 4). The results showed that the impact strength of the composites was significantly improved by even small amounts of single-wall nanotubes [19].

In dentistry, adhesion and plaque formation onto PMMA-based resins is a common source of oral cavity infections and

FIGURE 4: (a) SEM micrograph of as-received PMMA particles (scale bar: 200 μm); (b) SEM micrograph of PMMA particles with nanofibrils spread over the surface (4 wt% nanofibrils) (scale bar: 50 μm).

FIGURE 5: SEM of standard (a) and nanopigmented PMMA (b) at $\times 100$ magnification [62].

stomatitis [55, 56]. Some researchers showed that the addition of metal nanoparticles such as TiO_2 , Fe_2O_3 , and silver to PMMA materials could increase the surface hydrophobicity to reduce bimolecular adherence [57–59].

In recent years, metal oxide nanoparticles (e.g., TiO_2 , silver) have been largely investigated for their performances as antimicrobial additives. In particular, TiO_2 is now considered as a low-cost, clean photocatalyst with chemical stability and nontoxicity [60, 61]. Laura et al. prepared the PMMA composites, adding TiO_2 and Fe_3O_2 nanoparticles, for simultaneously coloring and/or improving the antimicrobial properties of PMMA (Figure 5). PMMA containing nanoparticles showed a lowered *Candida albicans* (*C. albicans*) cells adhesion and a lower porosity, compared to standard PMMA. Because high porosities have been considered a critical drawback for PMMA in prosthodontics applications, metal oxide nanoparticles might be suitable additives for the improvement of PMMA formulations [62]. These results indicated that nanostructured metal coloring additives are a promising means for producing nontoxic hybrid materials with antimicrobial properties for dentistry applications.

Silver (Ag) has been well known for its antimicrobial properties and has a long history of application in medicine with well-tolerated tissue response and low toxicity profile.

The antimicrobial action of Ag may be proportional to the amount of released bioactive silver ions (Ag^+) and their interaction with bacterial cell membranes [63–66]. Silver nanoparticles can kill all pathogenic microorganisms, and no report as yet has shown that any organism can readily build up resistance to them. In dentistry, some studies of the antibacterial effect of dental materials incorporating silver were made [67–69]. Yoshida et al. showed that a resin composite incorporated with silver-containing nanomaterials had a long-term inhibitory effect against *S. mutans* [70]. Laura et al. formulated PMMA-silver nanocomposites, with fairly good dispersion of silver nanoparticles in the polymer matrix. And the results showed that PMMA-silver nanocomposites significantly reduced adherence of *C. albicans* and did not affect metabolism or proliferation. They also did not appear to cause genotoxic damage to cells. These results demonstrated that PMMA-silver nanoparticles might be a kind of suitable candidates to produce nontoxic materials with antimicrobial properties for use in dentistry [71]. The same results were demonstrated in the study of Monteiro et al., where silver nanoparticles were incorporated in the PMMA denture resin to attain an effective antimicrobial material to help control common infections involving oral mucosal tissues in complete denture wearers, because the nanocomposites had good

efficacy against *C. albicans* [59]. Silver has been shown to be a biocompatible material being used for a range of medical devices. Recently, Ag nanoparticles with a high surface area were incorporated into resins to reduce the Ag particle concentration necessary for efficacy, without compromising the composite color and mechanical properties. Regarding the durability, Ag-containing nanocomposites showed long-term antibacterial effects and inhibited *S. mutans* growth for more than 6 months [72–74].

However, although there are a lot of the studies on nanoresins, most of them belong to basic researches. We hope in the near future that nanoresin can be widely used in the field of clinical prosthodontics.

3. Brief Description of Nanomaterials' Applications in Other Aspects of Dentistry

Nanotechnology and nanomaterials are widely carried out not only in the field of prosthodontics, but also in other areas of dentistry, such as oral medicine, oral surgery, and preventive dentistry, and so forth. We believe that with the study of nanotechnology and nanomaterials research dental medicine will be able to make great progress and open up new ways to benefit patients.

3.1. The Application of Nanocomposites for Oral Medicine.

Currently, the main material of oral medicine is composite resin filling materials, and composite resin repairing dental defects has been of more than 40 years of history. The properties of composite resin have some shortcomings such as polymerization shrinkage being easy to form microleakage, low wear resistance, and low mechanical strength. Because nanoparticles have unique properties, such as many unpaired atoms, less surface defects, and large surface area, combined with polymer with the occurrence of strong chemical or physical binding, thus they have higher strength and toughness. Many kinds of nanoparticles have been widely used in oral medicine composite resin, such as nanosilica, nanozirconia, nanohydroxyapatite, and nanotitanium oxide, and so forth [51]. Addition of nanoparticles in composite resin can increase strength and toughness of the composite resin. Due to small particle size, composite resins with nanoparticles significantly reduce the effect of polymerization shrinkage and dramatically improve physical properties [75]. In addition, composites containing nanofillers resulted in smooth surfaces with their ease of polish ability, increased abrasion resistance, and surface hardness [76].

3.2. The Application of Nanocomposites for Oral Surgery.

Mandibular bone defects caused by the cyst are a kind of common diseases in oral surgery. Facial deformities caused by the bone defects seriously affect the appearance of the patients. Exogenous bone implants have been commonly used to repair this kind of bone defects, which, however, have poor biocompatibility, higher probability of postoperative infection. Some nanomaterials such as nanohydroxyapatite have excellent biocompatibility, which have been shown to have high potential as repair materials to treat the oral

diseases caused by bone defects. They not only can be used as scaffolds for new bone formation, but also have the ability to promote the osteogenic differentiation and biomineralization of cells, which play very important roles in the bone defect repair. For example, the addition of nanohydroxyapatite, a simple operation, can not only fill the bone defects and avoid the infection problems, but also obviously induce new bone induction, which suggests that it should have high potential to be widely used in oral surgery.

At another important aspect, the oral cancer has become a serious threat to human life. The biggest problem of the oral cancer chemotherapy is currently low local concentration of the drug and large systemic toxicity. Precise dose delivery to malignant tissue in radiotherapy is of great importance for effectively treating the cancer efficacy while minimizing morbidity of surrounding normal tissues. Several researches have showed that some nanoparticles such as magnetic nanoparticles could be used for tumor targeted therapy. Due to the small diameter of the nanoparticles, they can be directly with the bloodshed to evenly penetrate into the tumor site and tumor tissue, improving the therapeutic index of drugs, reducing the toxicity of drugs, and getting the desired effect of complete tumor regression [77–79]. Therefore, the use of nanomaterials is one of promising means to accurately highlight tumor cells and deliver therapeutics specifically to the tumor to maximize tumor cell killing and normal tissue sparing.

3.3. The Application of Nanocomposites for Preventive Dentistry.

The purpose of preventive dentistry is the early prevention of tooth decay rather than invasive restorative therapy. However, the prevention of early caries lesions is still challenge for dental research. Recent studies show that nanotechnology might provide novel strategies in preventive dentistry. Biomimetic approaches have been used to develop nanomaterials for inclusion in a variety of oral health-care products, such as liquids and pastes that contain nanoapatites for biofilm management at the tooth surface and products that contain nanomaterials for the remineralization of early submicrometre-sized enamel lesions. Dental caries is caused by bacterial biofilms on the tooth surface. Nanocomposite surface coatings can make the tooth surface easy to clean, prevent the pathogenic consequences, and reduce bacterial adherence [80–82]. The toothpastes that contain the apatite nanoparticles can be used for biofilm management nanomaterials and can be used as an approach for remineralization of submicrometre-sized enamel lesions [9, 83, 84]. However, currently these oral prevention products with nanoparticles are also still in the research stage and intensive study is necessary for clinical application in the future.

4. Concluding Remarks

Future development of prosthodontics technology has been recognized to be dependent on the progress of materials science. Nanomaterials have been playing a significant role in basic scientific innovation and clinical technological change of prosthodontics. In this paper, the latest research progress on the applications of nanometals, nanoceramic, nanoresin,

and other nanomaterials in prosthodontics was reviewed, which clearly shows that many properties, such as modulus elasticity, surface hardness, polymerization shrinkage, and filler loading, of materials used in prosthodontics can be significantly improved after their scales were reduced from micron-size into nanosize by nanotechnology and that the performances of composites can be also enhanced by adding appropriate nanomaterials. We hope that this review article could provide some valuable elicitation for the future scientific and technological innovations in the related field.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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