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RESEARCH ARTICLE

# "NANOTECHNOLOGY" - THE NEW ERA OF PROSTHODONTICS

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ABSTRACT

Cloude Levi Strauss and Winfred Phillips said that, "You have to be able to fabricate things, you have to be able to analyze things, and you have to be able to handle things smaller than ever imagined in ways not done before". Many researchers believed that in future, scientific devices that are dwarfed by dust mites may one day be capable of grand biomedical miracles. The word 'Nano' is derived from the Greek word for "dwarf". Today, the revolutionary development of nanotechnology has become the most highly energized discipline in science and technology. Nanotechnology is extremely diverse and multidisciplinary field, ranging from novel extensions of conventional physics to completely new approaches based upon molecular self assembly to developing new materials and machines with nanoscale dimensions. The growing interest in the future of dental application of nanotechnology leads to emergence of "Nanodentistry" which involves the maintenance of oral health by the use of nanomaterials, biotechnology and dental nanorobotics. The recent developments, particularly of nanoparticles and nanotubes, the materials developed from such as the hollow nanospheres, core shell structures, nanocomposites, nanoporous materials, and nanomembranes will play a growing role in materials development for the dental fraternity. This paper is an attempt to give an over view about the nanomaterials and nanotechnology and its applications in the field of Prosthodontics.



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## INTRODUCTION

Man has been trying to study the natures smaller scale technology and has been progressively investigating smaller and smaller level of nature's creation. The first use of the concept 'nano-technology' was by a Physicist Richard Feynman on 29th December, 1959. Nanotechnology is the science and technology of precisely manipulating the structure of matter at the molecular level. Nanotechnology can be defined as the science and engineering involved in the design, synthesis, characterization, and application of materials and devices whose smallest functional organization in at least one dimensions on the nanometer scale or one billionth of a meter (Freitas, 2005). Growing interest in the future medical applications of nanotechnology is leading to the emergence of a new field called nanomedicine - the science and technology of diagnosing, treating and preventing disease and traumatic injury, of relieving pain and of preserving and improving human health using nanoscale-structured materials, biotechnology and genetic engineering and eventually complex molecular machine systems and nanorobots. Similarly, the application of the principles of nanotechnology in the field of dentistry has led to the conceptual development of "nanodentistry". It is foreseen as a means of making possible the maintenance of near-perfect oral health through the use of nanomaterials, biotechnology including tissue engineering and nanorobotics. In dentistry, potential applications of nanotechnology were discussed by KE Drexler and EM Reifman. Nanotechnology can be applied to various fields of dentistry such as local anesthesia, hypersensitivity, implants, dentrifices, orthodontic treatment, nanocomposites, impression materials, nanoneedles and bone replacement materials.

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### Need for nanotechnology in dentistry

"NANO" is a buzz word for a reason. By the close of the 20th Century, large-scale industrial operations were run by computers and robots, far exceeding imaginations of 19th Century science fiction writers. This century will see the miniaturization and increased capacity of many things made with materials. Material scientists are challenged to control and build nanostructures to test, discover and utilize the potential which exists. Materials reduced to the nanoscale can suddenly show very different properties compared to what they exhibit on a nanoscale, enabling unique applications. For instance, opaque substances become transparent (copper); inert materials become catalysts (platinum); stable materials turn combustible (aluminum); solids turn into liquids at room temperature (gold); insulators become conductors (silicon). Materials such as gold, which are chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscale. Much of the fascination with nanotechnology stems from these unique quanta and surface phenomena that matter exhibits at the nanoscale. It is this desirable alteration in the physico-chemical properties of a bulk material when reduced to a nanoscale that highlights the importance of applied nanotechnology in various fields including dentistry. Like other branches of dentistry, restorative dentistry including prosthodontics and implant dentistry has made remarkable progress with respect to nanotechnology. In prosthodontics, various types of nanomaterials are added to improve the properties of commonly used materials like resin denture base material, ceramics, polyvinyl siloxane impression material, maxillofacial materials, luting cements, etc. Research on addition of nanoparticles in this regard will promote the usage of such materials with greater efficiency and durability will definitely be of great advantage to dentists and patients undergoing prosthodontic treatment

## Nanoparticles in resins in Polymethyl methacrylate (PMMA)

Nanoparticles are added to polymethyl methacrylate as antimicrobial agents to increase the viscoelastic property of resins. Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis. Candida albicans adhesion and biofilm formation are regarded as essential prerequisites for denture stomatitis. Oral pathological condition like denture stomatitis is mainly caused by adherence of biofilm onto the denture base. Incorporation of nanoparticles into the denture base materials is mainly in the form of silver and platinum nanoparticles as an effective antimicrobial agent. 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 (Freitas, 2005; Acosta-Torres *et al*., 2012; Monteiro *et al*., 2012). The study was conducted to evaluate the effect of denture base resin containing silver nanoparticles (nano-silver) on Candida albicans adhesion and biofilm formation. The results showed that bioactivity and biomass of C. albicans biofilm successively decreased with increasing nano-silver solution concentration. Denture base resin containing nano-silver had no effect on adhesion at low concentrations, but it exhibited anti-adhesion activity at a high concentration (5%). For 72 h biofilm formed on the resin specimens, the thickness and live/dead cell ratio were successively reduced with increasing nano-silver concentrations. Nano-silver had antifungal activity and inhibited C. albicans biofilm formation. Antifungal activity and an inhibitory effect on adhesion and biofilm formation by denture base resin containing nano-silver were discovered, especially at a higher concentration (Li *et al*., 2016). The study evaluated a denture base resin containing silver colloidal nanoparticles through morphological analysis to check the distribution and dispersion of the particles in the polymer and by testing the silver release in deionized water at different time periods. The results showed silver particles were not detected in deionized water regardless of the silver nanoparticles added to the resin and of the storage period. Micrographs showed that with lower concentrations, the distribution of silver nanoparticles was reduced, whereas their dispersion was improved in the polymer. Moreover, after 120 days of storage, nanoparticles were mainly located on the surface of the nanocomposite specimens. This study concluded that, incorporation of silver nanoparticles in the acrylic resin was evidenced. Moreover, silver was not detected by the detection limit of the atomic absorption spectrophotometer used in this study even after 120 days of storage in deionized water. Silver nanoparticles are 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 (Monteiro *et al*., 2012).

A study was done to evaluate the antimicrobial property of a denture base as characterized by the synthesis of a modified PMMA denture acrylic loading platinum nanoparticles (PtN). The results of this study showed PtN was successfully loaded and uniformly immobilized into PMMA denture acrylic with a proper thermal stability and similar surface morphology as compared to control. PtNC expressed significant bacterial anti-adherent effect rather than bactericidal effect above 50 mg/L PtN loaded when compared to pristine PMMA (P=.01) with no or extremely small amounts of Pt ion eluted. This is the first report on the synthesis and its antibacterial activity of Pt-PMMA nanocomposite. PMMA denture acrylic loading PtN could be a possible intrinsic antimicrobial denture material with proper mechanical characteristics, meeting those specified for denture bases. For clinical application, future studies including biocompatibility, color stability and warranting the long-term effect were still required (Nam, 2014). Improvements in the viscoelastic properties of denture base materials were noted. Hamada Zaki Mahross et al investigated the effect of silver nanoparticles (AgNPs) incorporation on viscoelastic properties of acrylic resin denture base material. The results showed that AgNPs incorporation within the acrylic denture base material can improve its viscoelastic properties (Symposium: Nanotechnology in dentistry, 2015). Other nanoparticles such as $ZrO_2$, $TiO_2$, and carbon nanotubes (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 (Mahross and Baroudi, 2015; Hua *et al*., 2013; Mohammed and Mudhaffar, 2012; Hong *et al*., 2003).

## Nanoceramics

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 (Cooper *et al*., 2002). Nanoceramic refers to the ceramic material with nanoscale dimensions in the microstructures phase. Compared with the conventional ceramics, nanoceramics have a unique property, which makes it become the hot topic 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 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. 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 (Akova *et al*., 2008). 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 in clinical cases has been often reported. To improve mechanical properties of glass ceramics based on lithium disilicate, researcher 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 somewhat lower elastic Modulus but higher hardness than the conventional lithium disilicate (Raj and Mumjitha, 2014).

**Nanoparticles in Impression materials**

Improved physical properties of polyvinylsiloxane impression materials were done by addition of nano-sized fumed silica. The study was carried out in which polyvinylsiloxanes (PVS) were used as dental impression materials, formulated with the variation of loading combination of six types of fillers including nano-sized fumed silica. The fillers were blended with three types of silicone polymers together with cross-linker and inhibitor in base paste and with plasticizer and platinum catalyst in catalyst paste. By replacing parts of crystalline quartz with other fillers, the setting time became much faster. The test group in which quarter of quartz was replaced with fumed silica showed the most ideal working and setting time for clinical use. There was a negative correlation between pH and setting time ($p < 0.05$). Combining the fumed silica was effective in increasing the viscosity, tensile strength and maximum% strain. Combining the diatomaceous earth reduced the setting time and maximum% strain, and dramatically increased the viscosity and tensile strength. The best modulation of physical properties of PVS material was possible by combining fillers during the formulation (Persson *et al*., 2012).

**Nanotechnology in maxillofacial prosthodontics**

The study conducted to evaluate the effect of chemical disinfection and accelerated ageing on the dimensional stability and detail reproduction of a facial silicone (Silastic MDX 4-4210) with different types of nanoparticle. Chemical disinfection accelerated ageing affected the dimensional stability of the facial silicone with statistically significant results. Thesilicone's detail reproduction was not affected by these two factors regardless of nanoparticle type, disinfection and accelerated ageing (Choi *et al*., 2011).

**Nanoparticles in hybrid resin luting cements**

A study investigated the influence of nanoparticle loading level on properties of experimental hybrid resin luting agents. Incorporation of nanoparticles was associated with observation of clusters in the SEM analysis. The clusters were more frequent for higher nanoparticle loadings. It was concluded that modest incorporation of nanoparticles may improve the properties of resin luting materials. Nanofiller mass fractions above 2.5% should however be avoided because they may be detrimental to the properties of the resin luting agents (Pesqueira *et al*., 2012).

**Conclusion**

In this article, the latest research progress on the applications of nanometals, nanoceramic, nanoresin and other nanomaterials in prosthodontics was reviewed, which clearly shows that 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 also be enhanced by adding appropriate nanomaterials. This review article could provide some valuable information for the future scientific and technological innovations in the related field. 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 changes of prosthodontics.

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