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Review Article

Effect Of Nanoparticle Addition On Polymethylmethacrylate Resins

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Abstract

Polymethylmethacrylate (PMMA) is the most commonly used material in the manufacture of prosthetic base materials because it has a combination of convenient properties, such as easy laboratory manipulation, ease of finishing and polishing, light, economical, stable performance, proper aesthetics and color matching ability and non-toxic. However, the polymethylmethacrylate resin denture base material is not ideal in all respects. This article reviews the development of acrylic prosthetic base resin in the last few years. Special attention is paid to the effect of nanoparticles with the properties of polymethylmethacrylate. The review, in addition to scientific reviews, reports, and abstracts, was based on studies on the effect that nanoparticles were PMMAs in 2000 and 2019. The findings of the review may be observable, do not have the ideal prosthetic base material, but with some modifications, the property of PMMA can be improved by the addition of nanoparticle.

Keywords: Polymethylmethacrylate; Nanoparticles; Titanium Dioxide Nanoparticles; Zirconium Oxide Nanoparticles; Silver Nanoparticles; Zinc Oxide Nanoparticles; Seashell nanopowder

Abbreviation

PMMA: Polymethylmethacrylate; TiO2NPs: Titanium dioxide nanoparticles; ZrO2NPs: Zirconium oxide nanoparticles; AgNPs :Silver nanoparticles; ZnO: Zinc oxide nanoparticles; C.Albicans: Candida Albicans.

Introduction

Polymethylmethacrylate has been widely used as removable denture base materials, orthodontic appliance, facial prostheses, and temporary tooth restorative materials [1]. PMMA has advantages such as ease manipulation, ease in finishing and polishing, light in weight, economical, stable performance intra-oral tissues, having good aesthetic and color matching ability, and free from toxicity [2-4]. The PMMA is not ideal in all aspect, although it has such good properties. PMMA has a poor surface/mechanical properties and limited antimicrobial properties [5]. Because PMMA has poor impact strength, fractures often occur in prostheses. Therefore, it is important to increase impact strength to prevent prosthetic fractures [6,7].Various fillers, metal oxides, and carbon graphite fibers are incorporated into the composition to solve these problems and to increase the mechanical properties of the resin [2,8]. One of the most promising approaches recently used to overcome these disadvantages is to incorporate various nanoparticles into the PMMA to act as the reinforcing material [1]. According to the results of the studies, the properties of the polymer nanocomposites have proven to be dependent on the nanoparticle [9-11]. The type of incorporated nanoparticles, shape, size, concentration and interaction of the nanoparticles with the polymer matrix determine the properties of the polymer nanocomposite [12]. The modulus, strength, ductility, antimicrobial properties and aesthetic properties of PMMA have been improved by the addition of nanoparticles [13]. The mechanical properties of polymer nanocomposites depend on the dispersion and adhesion of the fillers between the filler and matrix. Surface treatment with silane coupling agents is applied to the fillers to increase this compatibility between the filler and the matrix [14,15]. The homogeneous distribution and good adhesion of nanoparticles in the resin matrix increase the flexural properties of the polymer nanocomposites [14]. Although there are various nanoparticles; in the literature nanoparticles such as aluminum oxide (Al_2O_3), zirconium oxide (ZrO_2), titanium dioxide (TiO_2), zinc oxide (ZnO), silicon dioxide(SiO_2) and silver (Ag) has often been used [4,16,17]. Nanoparticles are characterized by their small size, large surface area and intense interface interactions with the polymer matrix. The nanoparticles can thus enhance the physical and optical properties of the polymer matrix. In addition, they can provide resistance to environmental stress, cracking and aging [17].

Zirconium Oxide Nanoparticles

Zirconium oxide nanoparticles (ZrO_2NPs) have recently been noted for their excellent biocompatibility. However, they are thought to be less likely to change aesthetics than other metal oxide nanoparticles because they are white in color [2]. ZrO_2NPs are not only biocompatible materials but also have good wear and corrosion resistance. In addition to these features, ZrO_2NPs have good toughness and mechanical strength properties [18-20]. ZrO_2NPs are often incorporated into polymers to mechanically reinforce. In order to eliminate the possibility of aggregation and increase the compatibility with the polymer matrix, silane coupling agents are applied to the surface of ZrO_2NPs [14,15]. The stresses resulting from good dispersal of ZrO_2NPs are transferred from weak PMMA matrix to strong nanoparticles [20].

Increased contact between teeth during chewing causes wear on the prosthetic surfaces. Low wear resistance limits the use of PMMA [21]. Mohammed and Mudaffar investigated the effect of modified zirconium oxide nanoparticles on abrasive wear resistance of polymethylmethacrylate. Abrasive wear was tested using different denture cleaning materials. There was an increase observed in abrasive wear resistance at 3 wt% and 5 wt% nano ZrO_2 concentrations. The reduction in abrasive wear is thought to be due to the physical properties of ZrO_2NPs. In addition to these results, water absorption and solubility decreased, and this was attributed to the fact that ZrO_2NPs were water insoluble. As a result of the addition of ZrO_2NPs, porosity has also decreased. The addition of ZrO_2NPs to the material increased the density and decreased porosity [22]. This relationship between density and porosity is consistent with the study conducted by Laura., *et al*. [13].

Ahmet and Ebrahim investigated the effect of ZrO_2NPs (four concentrations 1.5 wt%, 3 wt%, 5 wt%, and 7 wt%) on the flexural strength, fracture toughness and hardness of heat-polymerized acrylic resin. The control groups had the lowest mean flexural strength values. PMMA samples containing 7 wt% ZrO_2NPs had the highest mean flexural strength values. The test results show significant improvement in tensile strength values of PMMA samples fortified with ZrO_2NPs. In addition, it was observed that hardness values increased in all groups compared to the control group [3].In addition to these results, fracture toughness value at the concentration of 3 wt% ZrO_2NPs reached the maximum. When the 3 wt% concentration was exceeded, there was no significant improvement in the fracture toughness value. This is likely to be due to the full saturation of the polymer matrix with ZrO_2NPs [3,23].

Gad., *et al*. investigated the effect of $Zr0_2$NPs (three concentrations 2.5 wt%, 5 wt%, and 7.5 wt%) on the translucency and tensile strength of the PMMA denture base material. According to the results of the study, mean tensile strength values in all test groups were higher than the control group. Maximum tensile strength was observed in the group containing 7.5 wt% ZrO_2NPs. Translucency values were lower in the experimental groups than in the control groups. The translucency values of the experimental group containing 2.5 wt% ZrO_2NPs were higher than the 5 wt% and 7.5 wt% ZrO_2NPs. In other words, as the concentration of ZrO_2NPs increased, the translucency values were adversely affected [20].

The rough surface may affect tissues health due to microorganism accumulation. Surface roughness stimulates the adhesion and proliferation of Candida albicans, which are important in the pathogenesis of prosthetic stomatitis. The increase in the amount of Candida albicans may cause an increase in the incidence of caries, gingival and periodontal diseases and increased stomatitis in the oral tissues adjacent to the material [24]. Gad., *et al*. investigated the effect of ZrO_2NPs on C.albicans adhesion of cold-cured acrylic resin. As a result of the study, it was reported that C.albicans adhesion and proliferation were decreased in ZrO_2NPs added samples [24].

Ihab and Moudhaffar investigated the effect of ZrO_2NPs on the impact strength, surface roughness, transverse strength, radioopacity of heat cured acrylic denture base material. As a result of this study, it was observed that the impact and transverse strength values increased in the group containing 5 wt% ZrO_2NPs. However, this increase was not observed in the group containing 7 wt% ZrO_2NPs. They reported that this was due to the agglomeration of ZrO_2NPs. In addition, the addition of modified ZrO_2NPs has been reported to be associated with an increase in radiopacity [25].

Titanium dioxide nanoparticles

Titanium dioxide nanoparticles (TiO_2NPs) have superior mechanical properties, the modulus of elasticity is around 230 GPa. The use of TiO_2 to improve the mechanical properties of dental materials is highly effective, but agglomeration within the material is an important disadvantage. Various processes can be applied to the TiO_2 surface in order to eliminate agglomeration [9]. Titanium dioxide nanoparticles have various good properties such as antimicrobial, cheap, biocompatible, white color, chemically stable, free toxicity and corrosion resistant. In the literature, the addition of TiO_2NPs to the polymeric material has been shown to affect the electrical, optical, chemical and physical properties of the hybrid material [11,26].

TiO_2NPs have proved to exhibit antimicrobial properties, because of TiO_2-induced photocatalytic production of cytotoxic oxygen radicals [27]. As a result of doping with metal or metal oxides to TiO_2 nanoparticles, the photocatalytic activity of TiO_2 nanoparticles has been improved and consequently, the disinfection effect has increased [28].

Studies have shown that TiO_2NPs are effective against various microorganisms such as *Candida albicans, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Lactobacillus acidophilus*. Due to their antimicrobial properties, TiO_2NPs have been added to various biomaterials [11,29-31].

In their study, Alrahlah and Fouad reported that antimicrobial behavior of PMMA increased significantly by decreasing bacterial adhesion with increasing TiO_2 ratio. PMMA groups were compared at concentrations of 0, 1 wt% and 3 wt% containing TiO_2NPs. As the concentration of the nanoparticles increased, the number of adherent *P. aeruginosa* was reported to decrease [32].

Moslehifard and Shirkavand investigated the effect of TiO_2NPs (three concentrations 0.5 wt%, 1 wt%, 2 wt%) on the tensile strength of heat-curing acrylic resin. The researchers observed that the addition of 1 wt% TiO_2 nanoparticle increased tensile and impact strength but adversely affected its color [33].

Ghahremani., *et al*. showed that color modified acrylic resin powder in combination with 1 wt% TiO_2NPs had higher tensile and impact strength than the conventional acrylic resin [34].

According to the results of another study, it was observed that the impact strength, transverse strength, and surface hardness values of heat cured acrylic resin were increased by 3 wt% TiO_2NPs. This may be due to the increase of the connection between the nanofillers and the matrix as a result of the particle size reduction. In addition, water sorption and solubility are reported to decrease [35].

Sodagar., *et al*. found that 0.5 wt% and 1 wt% of TiO_2 and SiO_2 nanoparticles were added to PMMA and the mechanical properties of the material were affected negatively. As the TiO_2 concentration increased, the flexural strength values were decreased. These findings indicate that TiO_2 nanoparticles negatively affect the degree of conversion that occurs in PMMA and leads to an increase in the level of unreacted monomer [11].

Zhang., *et al*. investigated the effect of TiO_2NPs (four concentrations 1 wt%, 3 wt%, 5wt%, and 7 wt%) on the on tribological behavior of PMMA. The mean tensile strength of the PMMA group without nanoparticle was 98 MPa. TiO_2NPs added PMMA groups have been reported to increase the mean tensile strength values. The most ideal tensile strength value was found in the addition of 3% TiO_2NPs. The results also show that the addition of TiO_2NPs increases the wear resistance. Furthermore, the surface of the nanoparticle added group is reported to be smoother [36].

M. A. Ahmed., *et al*. investigated the effect of TiO_2NPs (1 wt% and 5 wt%) on the flexural strength, impact strength, and microhardness of two different types of heat-polymerized acrylic resin. As a result of the study, it was reported that the flexural strength values decreased and the microhardness values increased with the addition of TiO_2NPs. The highest impact strength was observed as a result of the addition of 1 wt% TiO_2NPs. However, it was observed that the decrease in impact strength values caused by the addition of 5 wt% TiO_2NPs is due to the fact that the resin cannot be distributed between the filling particles. The addition of 5 wt% TiO_2NPs resulted in an increase in the microhardness of the material. Increased value of microhardness provides higher wear resistance. It has also been reported that changes in the color of acrylic occur when the TiO_2NPs concentration exceeds 5 wt% [37].

Silver nanoparticles

Silver nanoparticles are generally preferred because of their antimicrobial properties. Silver nanoparticles show antimicrobial effects on many microorganisms such as Streptococcus mutans, Staphylococcus aureus, and Candida albicans [38-40].

Li., *et al*. investigated the effect of AgNPs (1 wt%, 2 wt%, 3wt%, 5wt%) on the Candida albicans adhesion and biofilm formation of heat-polymerized acrylic resin. As a result of the study, it was reported that C. Albicans biofilm formation decreased with an increasing amount of AgNPs. Biofilm formation decreased at a concentration of 5 wt%, but no effect was observed at lower concentrations [41].

Baki., *et al*. investigated the thermal and chemical effects of silver particles on PMMA. According to the results of this study, the use of 0.8 wt% and 1.6 wt.% AgNPs reduced the flexural strength and elastic modulus of microwave-polymerized acrylic resin. In addition, the glass transition temperature has been decreased by the addition of AgNPs into PMMA [42].

In the study conducted by Sodagar., *et al*. it was concluded that the silver nanoparticles had a negative effect on the flexural strength of PMMA [43].

Ghafari., *et al*. investigated the effect of AgNPs concentrations 5 wt% on tensile strength. As a result of the research, it has been reported that the tensile strength decreased in the samples participating in AgNPs [44].

Hamedi Rad., *et al*. investigated the effect of adding 5 wt% AgNPs into PMMA. Studied the changes in thermal conductivity, compressive strength and tensile strength values of PMMA. According to the results of this study, an increase in thermal conductivity and compressive strength values, and a decrease in tensile strength values were reported. In addition, they reported a brownish discoloration of the prosthesis as a result of the addition of 5% AgNPs [38].

Koroglu., *et al*. investigated the effects of adding different concentrations of AgNPs (0.3 wt%, 0.8 wt%, and 1.6 wt %) into conventional heat-polymerized acrylic resin and microwave-polymerized acrylic resin. The transverse strength and elastic modulus of microwave-polymerized acrylic resin containing 0.8% and 1.6 wt.% AgNPs decreased. However, these values have not changed as a result of the addition of AgNPs to the conventional heat-polymerized resin group. The addition of AgNPs had no effect on impact strength. The highest impact strength was observed in the conventional resin group, which was not added to AgNPs. The lowest impact strength was observed in the microwave-resin group with 0.8 wt% AgNPs. The highest flexural strength and elastic modulus values were observed in the microwave polymerized resin group with the addition of 0.3 wt% AgNPs. In both groups, the addition of AgNPs decreased the glass transition temperature [45].

Casemiro., *et al*. investigated the effect of the addition different amount of silver-zinc zeolite on the antimicrobial activity, flexural and impact strength of heat-polymerized acrylic resin and microwave-polymerized acrylic resin. As a result of the study, it has been reported that the flexural strength and impact strength significantly decreased. In addition, antimicrobial properties have been reported to increase. It is estimated that the decrease in these values will adversely affect the clinical performance of the prostheses and the possibility of fracture in the prostheses [46].

Zinc oxide nanoparticles

In a study by Salahuddin., *et al*. PMMA was reinforced with ZnONPs and nanotubes. As a result of the study, it was shown that the mechanical and thermal properties of the material were improved. As a result of the addition of ZnO nanotubes, it was observed that the impact strength increased and the flexural strength value increased as a result of the addition of ZnO nanoparticles. It has also been reported that the addition of 0.2-0.4 wt% ZnO increases the flexural strength but when this ratio is 0.8-1 wt%, the flexural strength decreases. It has also been shown that nanocomposites have higher thermal stability than pure PMMA [8].

Cierech., *et al*. investigated the effect of ZnONPs of PMMA. As a result of the study, the color of PMMA was slightly white. However, this bleaching was both clinically and aesthetically acceptable. Furthermore, there was no significant difference in the results of roughness between nanocomposite and pure PMMA [47].

Kamonkhantikul., *et al*. investigated the effect of silanized zinc oxide nanoparticles (1.25 wt%, 2.5 wt%, and 5 wt%) on the antifungal, optical, and mechanical properties of heat-polymerized acrylic resin. The nanoparticle surfaces were modified to prevent the possibility of aggregation. The maximum C.albicans reduction was observed in the group containing 5% silanized particles. When the silanized and nonsilanized groups containing the same amount of nanoparticles were compared, it was reported that C.albicans formation was reduced in the silanized group. Increased contact between silanized particles and C.albicans may increase the antifungal effect. Among the groups of nonsilanized, the antifungal effect was observed only in the group containing 5% nonsilanized particles. Higher flexural strength values were observed in silanized groups. In addition, the addition of ZnONPs has been reported to cause discoloration [48].

Seashell nanopowder

Seashells with the natural ceramic structure are similar to human bone and tooth structure. Karthick., *et al*. evaluated the hardness and tribological properties of the PMMA reinforced with seashell nanopowder. They concluded that tribological performance was improved considerably at 12 wt% seashell nanopowder content. The maximum microhardness value was observed in the presence of 12 wt% seashell nanopowder [21].

Conclusion

Nanoparticles have widespread use due to their superior properties and are being investigated extensively in recent years due to their advantages. However, more research and clinical studies are required for the use of nanotechnology for oral health. Long-term antimicrobial, toxic, physical and clinical effects of nanoparticles on PMMA should be investigated in further studies. Future discoveries would probably be that the antimicrobial effects of these nanoparticles would be at the maximum level and their toxicities would be minimal.

Conflict of Interest

We have no conflict of interest to declare.

Bibliography

1. Lee J., *et al*. "Development of long-term antimicrobial poly (methyl methacrylate) by incorporating mesoporous silica nanocarriers". *Dental Materials* 32.12 (2016): 1564-1574.
2. Abualsaud R., *et al*. "Reinforcement of PMMA Denture Base Material with a Mixture of ZrO 2 Nanoparticles and Glass Fibers". *International Journal of Dentistry* (2019): 1-11.
3. Ahmed MA and Ebrahim MI. "Effect of Zirconium Oxide Nano-Fillers Addition on the Flexural Strength, Fracture Toughness, and Hardness of Heat-Polymerized Acrylic Resin". *World Journal of Nano Science and Engineering* 04.02 (2014): 50-57.
4. Khalaf HA and Salman TA. "The Influence of Adding of Modified ZrO2-TiO2 Nanoparticles on Certain Physical and Mechanical Properties of Heat Polymerized Acrylic Resin". *Journal of Baghdad College of Dentistry* 27.3 (2016): 33-39.
5. Murakami N., *et al*. "Effect of high-pressure polymerization on mechanical properties of PMMA denture base resin". *Journal of the Mechanical Behavior of Biomedical Materials* 20 (2013): 98-104.
6. Yilmaz C and Korkmaz T. "The reinforcement effect of nano and micro fillers on fracture toughness of two provisional resin materials". *Materials and Design* 28.7 (2007): 2063-2070.
7. Yadav P., *et al*. "Effect of Incorporation of Silane-Treated Silver and Aluminum Microparticles on Strength and Thermal Conductivity of PMMA". *Journal of Prosthodontics* 21.7 (2012): 546-551.
8. Salahuddin NA., *et al*. "Reinforcement of polymethyl methacrylate denture base resin with ZnO nanostructures". *Applied ceramic technology* 15.2 (2018): 448-459.
9. Sun J., *et al*. "Improving performance of dental resins by adding titanium dioxide nanoparticles". *Dental Materials* 27.10 (2011): 972-982.
10. Xia Y., *et al*. "Nanoparticle-reinforced resin-based dental composites". *Journal of Dentistry* 36.6 (2008): 450-455.
11. Sodagar A., *et al*. "The effect of TiO2 and SiO2 nanoparticles on flexural strength of poly (methyl methacrylate) acrylic resins". *Journal of Prosthodontic Research* 57.1 (2013): 15-19.
12. Jordan J., *et al*. "Experimental trends in polymer nanocomposites - A review". *Materials Science and Engineering: A* 393.1-2 (2005): 1-11.
13. López-Marín LM., *et al*. "Biocompatible Metal-Oxide Nanoparticles: Nanotechnology Improvement of Conventional Prosthetic Acrylic Resins". *Journal of Nanomaterials* (2011): 1-8.
14. Gad MM., *et al*. "Influence of incorporation of ZrO2 nanoparticles on the repair strength of polymethyl methacrylate denture bases". *International Journal of Nanomedicine* 11 (2016): 5633-5643.
15. Tang E., *et al*. "Synthesis of nano-ZnO/poly (methyl methacrylate) composite microsphere through emulsion polymerization and its UV-shielding property". *Colloid and Polymer Science* 284.4 (2006): 422-428.
16. Alhareb AO., *et al*. "Influence of Al2O3/ Y-TSZ Mixture as Filler Loading on the Radiopacity of PMMA Denture Base Composites". *Procedia Chemistry* 19 (2016): 646-650.
17. Han Y., *et al*. "Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer". *Journal of Prosthetic Dentistry* 100.6 (2008): 465-473.
18. Ayad N., *et al*. "Effect of reinforcement of high-impact acrylic resin with zirconia on some physical and mechanical properties". *Revista de clínica e pesquisa odontológica* 4.3 (2008):145-151.

19. Gad M., *et al*. "The Reinforcement Effect of Nano-Zirconia on the Transverse Strength of Repaired Acrylic Denture Base". *International Journal of Dentistry* (2016):1-6.

20. Rahoma A., *et al*. "Effect of zirconium oxide nanoparticles addition on the optical and tensile properties of polymethyl methacrylate denture base material". *International Journal of Nanomedicine* 13 (2018): 283-292.

21. Karthick R., *et al*. "Mechanical and Tribological Properties of PMMA-Sea Shell based Biocomposite for Dental application". *Procedia Materials Science* 6 (2014): 1989-2000.

22. Ihab NS and Moudhaffar M. "Effect of modified nano-fillers addition on some properties of heat cured acrylic denture base material". *Journal of Baghdad College of Dentistry* 23.3 (2011): 23-29.

23. Vojdani M., *et al*. "Effects of aluminum oxide addition on the flexural strength, surface hardness, and roughness of heat-polymerized acrylic resin". *Journal of Dental Sciences* 7.3 (2012): 238-244.

24. Gad M and Al-Thobity A. "Inhibitory effect of zirconium oxide nanoparticles on Candida albicans adhesion to repaired polymethyl methacrylate denture bases and interim removable". *International Journal of Nanomedicine* (2017): 5409-5419.

25. Ihab NS and Moudhaffar M. "Evaluation the effect of modified nano-fillers addition on some properties of heat cured acrylic denture base material". *Journal of Baghdad College of Dentistry* 23.3 (2011): 23-29.

26. Reijnders L. "The release of TiO2 and SiO2 nanoparticles from nanocomposites". *Polymer Degradation and Stability* 94.5 (2009): 873-876.

27. Li Q., *et al*. "Antimicrobial nanomaterials for water disinfection and microbial control: potential applications and implications". *Water Research* 42.18 (2008): 4591-4602.

28. Trapalis CC., *et al*. "TiO2(Fe3+) nanostructured thin films with antibacterial properties" *Thin Solid Films* 433.1-2 (2003): 186-190.

29. Su W., *et al*. "Preparation of TiO2/Ag colloids with ultraviolet resistance and antibacterial property using short chain polyethylene glycol". *Journal of Hazardous Materials* 172.2-3 (2009):716-720.

30. Maneerat C and Hayata Y. "Antifungal activity of TiO2 photocatalysis against Penicillium expansum in vitro and in fruit tests". *International Journal of Food Microbiology* 107.2 (2006): 99-103.

31. Ohko Y., *et al*. "Self-sterilizing and self-cleaning of silicone catheters coated with TiO2 photocatalyst thin films: A preclinical work". *Journal of Biomedical Materials Research* 58.1 (2001): 97-101.

32. Alrahlah A., *et al*. "Titanium Oxide (TiO2)/polymethylmethacrylate (PMMA) denture base nanocomposites: Mechanical, viscoelastic and antibacterial behaviour". *Materials (Basel)* 11.7 (2018): 1096.

33. Shirkavad S and Moslehifard E. "Effect of TiO2nanoparticles on tensile strength of dental acrylic resins." *Journal of Dental Research, Dental Clinics, Dental Prospects* 8.4 (2014): 197-203.

34. Ghahremani L., *et al*. "Tensile strength and impact strength of color modified acrylic resin reinforced with titanium dioxide nanoparticles". *Journal of Clinical and Experimental Dentistry* 9.5 (2017): e661-e665.

35. Alwan SA and Alameer SS. "The Effect of the Addition of Silanized Nano Titania Fillers on Some Physical and Mechanical Properties of Heat Cured Acrylic Denture Base Materials". *Journal of Baghdad College of Dentistry* 27.1 (2015): 86-91.

36. Zhang JG. "Study on friction and wear behavior of PMMA composites reinforced by HCl-immersed TiO2 particles". *Journal of Thermoplastic Composite Materials* 27.5 (2014): 603-610.

37. Ashour Ahmed M., *et al*. "Effect of Titanium Dioxide Nano Particles Incorporation on Mechanical and Physical Properties on Two Different Types of Acrylic Resin Denture Base". *World Journal of Nano Science and Engineering* 06.03 (2016): 111-119.

38. Hamedi-rad F., *et al*. "Effect of Nanosilver on Thermal and Mechanical Properties of Acrylic Base Complete Dentures". *Journal of Dentistry of Tehran* 11.5 (2014): 495-505.

39. Kassaee MZ., *et al*. "Antibacterial Effects of a New Dental Acrylic Resin Containing Silver Nanoparticles". 110.3 (2008): 1699-1703.

40. Wady AF., *et al*. "Evaluation of Candida albicans adhesion and biofilm formation on a denture base acrylic resin containing silver nanoparticles". *Journal of Applied Microbiology* 112.6 (2012): 1163-1172.

41. Li Z., *et al*. "Effect of a denture base acrylic resin containing silver nanoparticles on Candida albicans adhesion and biofilm formation". *Gerodontology* 33.2 (2016): 209-216.

42. U RX and Hazer B. "Silver nanoparticle incorporation effect on mechanical and thermal properties of denture base acrylic resins". *Journal of Applied Oral Science* 24.6 (2016): 590-596.

43. Dds AS., *et al*. "Effect of silver nanoparticles on flexural strength of acrylic resins §". *Journal of Prosthodontic Research* 56.2 (2012):120-124.

44. Ghaffari T1 and Hamedi-Rad F2. "Effect of Silver Nano-particles on Tensile Strength of Acrylic Resins". *Journal of Dental Research, Dental Clinics, Dental Prospects* 9.1 (2015): 40-43.

45. Köroğlu A., *et al*. "Silver nanoparticle incorporation effect on mechanical and thermal properties of denture base acrylic resins". *Journal of Applied Oral Science* 24.6 (2017): 590-596.

46. Casemiro LA., *et al*. "Antimicrobial and mechanical properties of acrylic resins with incorporated silver - zinc zeolite - part I". *Gerodontology* 25.3 (2008): 187-194.

47. Cierech M., *et al*. "Preparation and characterization of ZnO-PMMA resin nanocomposites for denture bases". *Acta of Bioengineering and Biomechanics* 18.2 (2016): 31-41.

48. Kamonkhantikul K., *et al*. "Antifungal, optical, and mechanical properties of polymethylmethacrylate material incorporated with silanized zinc oxide nanoparticles". *International Journal of Nanomedicine* 12 (2017): 2353-2360.

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