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Effect of Silver (Ag) Nanoparticles on Structural and Mechanical Properties of (PMMA) Blend and its Application for Denture Base

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ABSTRACT

The (PMMA-Ag) nano-composites films were prepared via photo polymerization method with different percentages (0.0%, 0.05%, 0.1%, 0.15% and 0.2%) of Ag. The structural, bacterial and mechanical properties of nano-composites were studied, FTIR spectra show a shift in peak position as well as a change in intensity. Scanning electron microscopy shows the surface morphology of the (PMM-Ag) nano-composites films. Three point bending testing, compressive strength, and impact strength were investigated and the results illustrate each mechanical property which improves the polymer characteristics. Then we reached that nano-composite materials are considered as the most important materials which are used as dental molds.

Keywords: Nano-composite, Structural, Bacterial and mechanical properties, Dental molds

INTRODUCTION

Polymer nano-composites homogenized with metal nanoparticles have become vital of all chemistry, physics, technology, and bio-engineering [1]. Recently, the polymerization of the organic monomer is performed initially and then the silver ions, as if the photo polymerization method has been reported to synthesize metal polymer nano-composites due to its unique advantages [2]. In this method, the reduction of metal ions and polymerization of monomer can be carried out simultaneously under the normal pressure at room temperature without using excessive reduction of agents [3].

This matter induces the formation of homogenously distributed metal nanoparticles in the chemical compound matrix. Therefore many papers are revealed on the radiation-induced synthesis of metal chemical compound nano-composites [4]. To our knowledge, there is no report on the use of UV-irradiation to produce PMMA/Ag nano-composite. In this paper, we employed UV-irradiation to produce PMMA/Ag nano-composite in which the metallic ions ($AgNO_3$) are reduced and there is polymerization of the methyl-methacrylate monomer. Where Ag-PMMA exhibits many characteristics as catalytic, electrical, optical, etc. it is often used in various electronic fields, and biomedical applications [5].

In recent years polymers are widely used in the manufacturing of teeth dental material, this refers to the mechanical properties. The polymer nano-composite materials showed good biocompatibility. The materials having high filler content demonstrated greater micro-hardness compared with commercially available bracket materials, as well as the polymer nano-composites have the same thermal conductivity as natural teeth [6-8].

In most of the dental materials, compressive strength characteristics are considered important, this is referred to the mastication which considers brittle materials scale according to International Organization for Standardization ISO: 9917[9].

Related Works

Gundogdu, et al., research studied the effect of surface treatments on the bond strength of soft denture lining materials to an acrylic resin denture base from results it appeared that Molloplast B exhibited significantly higher bond strength than Ufi Gel P. Altering the surface of the acrylic rosin dental plate base for 12-months with ortho phosphoric acid etching, it exaggerated bond strength [10].

Each of Elnaz Moslehifard and Saeed Shirkavand studied the effect of TiO_2 nanoparticles on the tensile strength of dental acrylic resins, the researcher observed that tensile strength increase with an increase in the nanoparticles percentage 1 wt% [11].

Baki, et al., studied the effect of silver nanoparticle incorporation on mechanical and thermal properties of denture base acrylic resins. The incorporation of AgNPs is generally used for antimicrobial potency, affected the transverse strength of the denture base acrylic resins relying on the concentration of nanoparticles. Tg was decreased with the addition of AgNPs for each denture base resins. Silver nanoparticle incorporation effect on mechanical and thermal properties of denture base acrylic resins [12].

Mariusz Cierech, et al., studied mechanical and physicochemical properties of newly formed ZnO-PMMA nano composites for denture bases. The studied results showed that no significant deterioration in the properties of acrylic resin that could disqualify the nano composite for clinical use increases hydrophilicity and hardness with absorbability among the traditional vary, which will make a case for the reduced microorganism growth on the denture base, as has been proven in a previous study [13].

The present study was conducted to study the effects of silver (Ag) nanoparticles on structural and mechanical properties of (PMMA) blend and its application for the denture. First, the silver nanoparticles were prepared with used modern and efficient methods for decreasing the nanoparticles size and then the PMMA was added with silver nanoparticles. The compressive strength illustrates that each mechanical properties improved the polymer characteristics. The nanocomposite materials were considered as the most important materials; impact strength was investigated and was used as a dental mold.

MATERIALS AND METHODS

Methyl methacrylate monomer's as matrix and silver nitrate ($AgNO_3$) is filler soluble in di-methyl formamide (DMF). For polymerizing the essentially metallic nano-composite (Ag-PMMA) ultraviolet-irradiation source with energy (125 watts) for about 15 min of irradiation time was used. The load percentages of $AgNO_3$ were (0, 0.05, 0.1, 0.15 and 0.2) wt%. The (FTIR) was measured by using the apparatus (Bruker), FE-SEM was measured by using the microscope type (SPMAA 3000 Angstrom Advanced Inc. USA 2008 FE-SEM Contact Mode). While the antibacterial activity of nano-silver-PMMA was tested by the diffusion method, using Mueller Hinton agar plate against the bacteria. The agar medium was seeded with the organisms by pour plate technique and was stuffed with completely different concentrations of silver nanoparticles embedded with polymer nano-composite resolution. The plates were pre-incubated for 1 hour at room temperature to make sure adequate diffusion and were eventually incubated at 37°C for 24 hours. After incubation, mechanical properties like flexural strength, flexural modulus, compressive and maximum force were tested. For flexural tests, bar-specimens were prepared by filling a Teflon mold of diameter (70 mm × 30 mm × 10 mm). The specimens were bent in a three-point transverse testing rig with 20 mm between the two supports (3-point bending). The rig was accurate to a mechanical testing machine (Instron, model 3344). All bend tests were carried out with a constant cross-head speed of 0.75 mm/min until fracture occurred. The load and the corresponding deflection were recorded. The flexural modulus (E), in MPa, and the flexural strength (σ), in MPa, were calculated using the following equations: [14]

$$\sigma=P/A$$

While the elastic modulus E was calculated using the below equation:

$$E=\sigma/\varepsilon$$

For compressive test bar specimens were prepared by filling a Teflon mold with diameter 10 mm and height 20 mm.

RESULTS AND DISCUSSION

Field Effect-Scanning Electron Microscopy (FE-SEM)

FE-SEM is used to investigate fully the effect of titanium carbide nanoparticles content and to examine the dispersion of nanocomposite particles in the polymers matrix. Figure 1 shows typical FE-SEM images of the (PMMA-Ag) nanocomposites without and with different concentrations of silver nanoparticles content. The surface morphology of the (PMMA-Ag) nano composites shows many aggregates or chunks randomly distributed on the top surface [15].

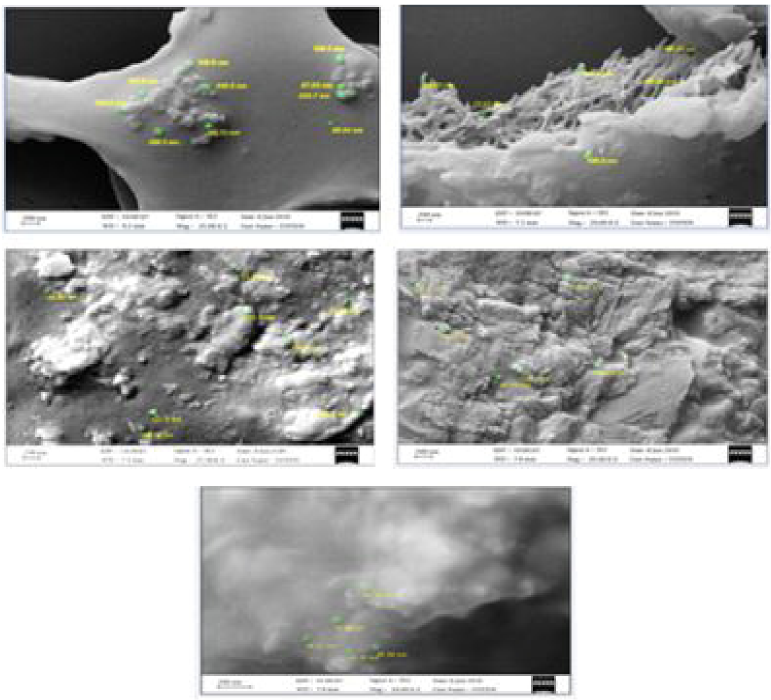

Figure 1 FE-SEM images of PMMA-Ag nanocomposites

Fourier Transform Infrared Analysis

Fourier Transfer Infrared Spectroscopy (FTIR) of PMMA tests material (PMMA) and PMMA-Ag, was performed using the apparatus (Bruker) existed in Al-Mustansyriah University, College of Science, Department of Chemistry. Figure 2 FTIR of PMMA and Ag-PMMA nanocomposite with the ratio of 0%, 0.05%, 0.1%, 0.15% and 0.2%, gives a good agreement comparing with other reference [16].

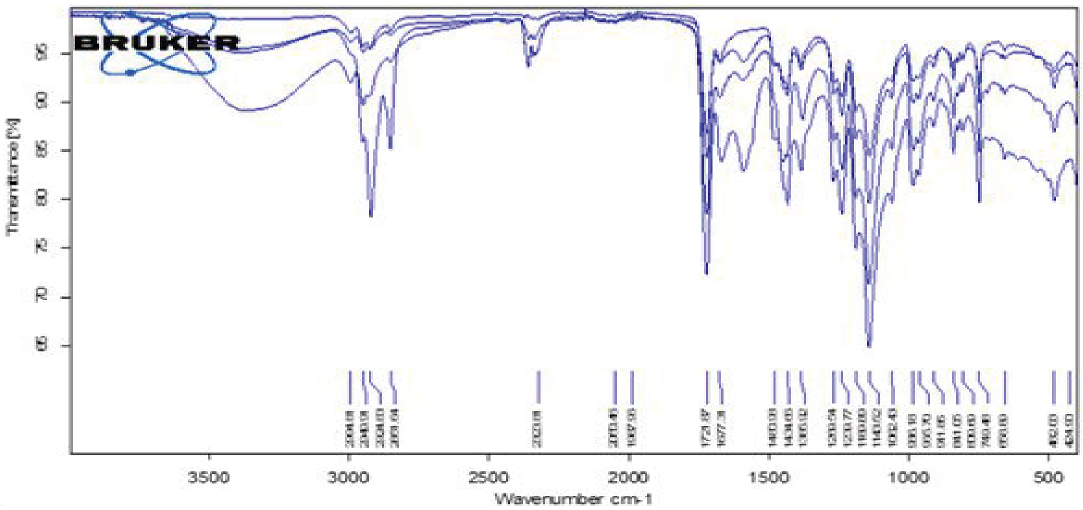

Figure 2 FTIR spectrum of PMMA-Ag nanoparticles with a different concentration

Bacterial Properties

Figure 3 shows the inhibition of streptococcus bacteria by the antibacterial activity. The inhibition zone method and measuring the concentration of bacteria was used to assess the antibacterial action of nano-composites and it is also considered as non-toxic material [17,18] (Figure 4).

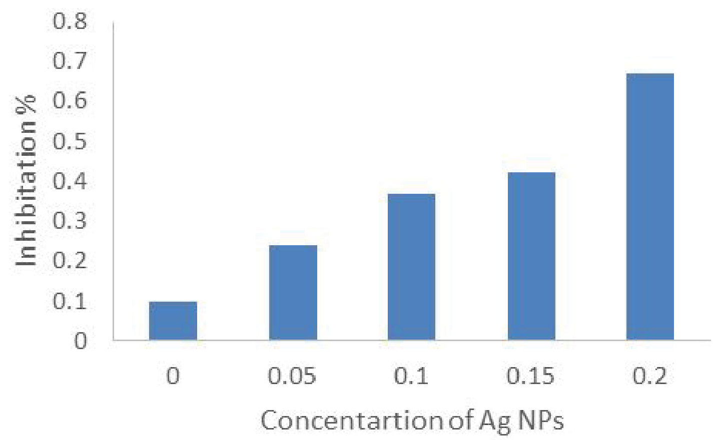

Figure 3 Change of streptococcus bacteria inhabitation with silver nanoparticle concentration

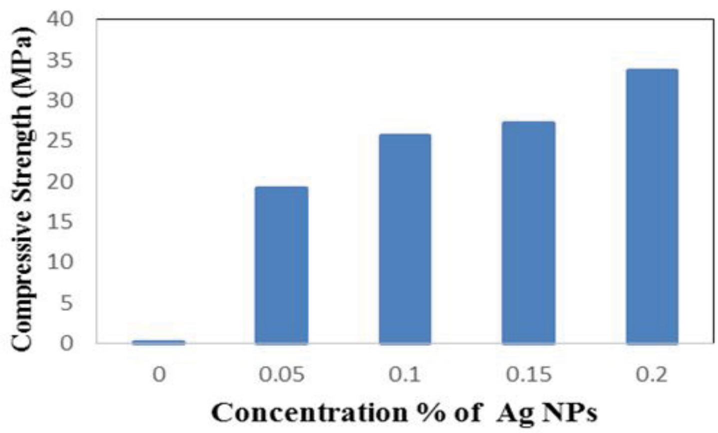

Figure 4 Change of compressive strength values with silver nanoparticle concentration

From Figure 5 it can be observed that there was an increase in the concentration of nanoparticles in polymer nanocomposite due to an increase of the fracture, this referred to the cohesive forces between the base material (polymer) and the additives material (AgNPs).

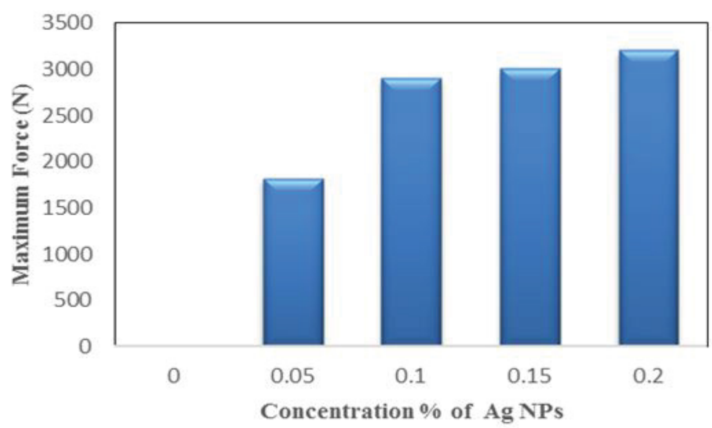

Figure 5 Change of maximum force values with silver nanoparticle concentration

From Figures 6 and 7 and using the equation, results showed that the bending coefficient of elasticity is increased by increasing the percentage of reinforcement by the addition of silver nanoparticles. In this study all materials investigated showed higher mean flexural strength values than ones recommended by the ISO, suggesting that these materials can be used as direct restorative materials, observed a higher mean FS value for nanocomposite [16,19].

IS=u/A (kJ/m^2)

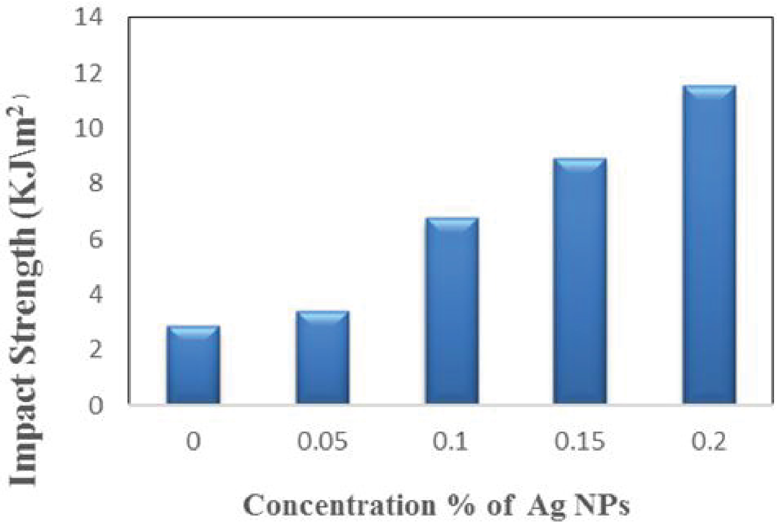

Figure 6 Change of impact strength with a concentration of silver nanoparticles

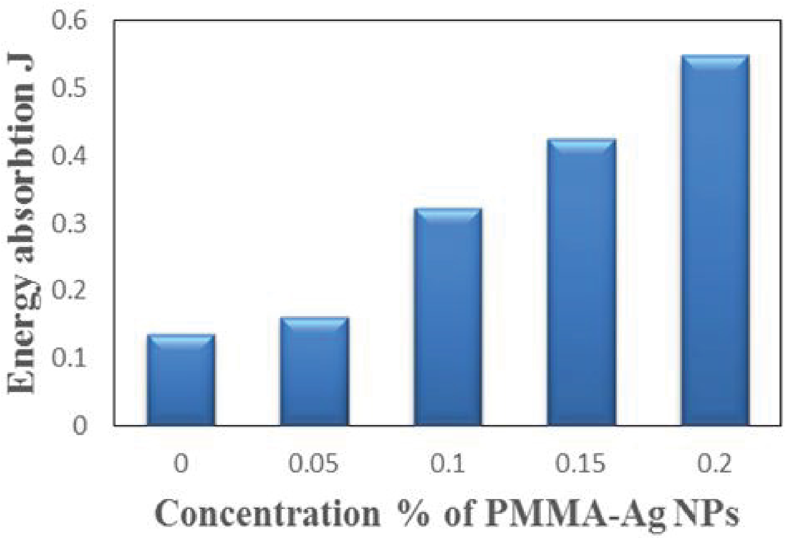

Figure 7 Change of energy absorption with silver nanoparticles concentration

CONCLUSION

Through the study of this experiment, we have concluded the following assumptions:

- The morphological study exploitation FE-SEM found that the common particles size was between 61.97 nm-76.42 nm
- From FTIR results appeared that every bond between polymer and nanoparticles are physical bonds this refers to the nature of nanocomposites
- The PMMA-Ag NPs nanocomposites take into account as bactericide materials against of streptococcus, additionally its non-toxic material
- The additive of the silver nanoparticle to PMMA polymer created the nanocomposites materials as glorious mechanical properties of dental molds

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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