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Structure and Mechanical Properties of (PMMA–ZrO_2–Ag) Nanocomposites for Medical Applications

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The (PMMA–ZrO_2–Ag) nanocomposites are fabricated by using casting method. Nano-zirconia and nano-silver are added to polymethyl methacrylate at different weight percent (0%, 0.75%, 1.5%, and 2.25%); nano-zirconia and nano-silver are attached to PMMA at equal weight percent. The effect of the ZrO_2 and Ag nanoparticles as promoters on the structural and mechanical properties of PMMA is characterized by optical microscopy, hardness and compression tests. The hardness of polymethyl methacrylate is increased with the increase in the ZrO_2 and Ag nanoparticles' concentration, but then is decreased after 2.25 weight percent. The compression strength of PMMA is gained with increasing nano-zirconia and nano-silver contents. The present work shows that the prepared samples can be used for dental applications.

Нанокомпозити (ПММА–ZrO_2–Ag) виготовляються методом лиття. Нано-діоксид цирконію та наносрібло додають у поліметилметакрилат (ПММА) за різного вагового відсотку (0%, 0,75%, 1,5% і 2,25%); нано-діоксид цирконію та наносрібло кріпляться до ПММА за рівних вагових відсотків. Вплив наночастинок ZrO_2 і Ag як промоторів на структурно-механічні властивості ПММА характеризується оптичною мікроскопією, тестами на твердість і стиснення. Твердість поліметилметакрилату збільшується зі збільшенням концентрації наночастинок ZrO_2 і Ag, але потім зменшується після 2,25 вагових відсотка. Міцність на стиск ПММА досягається зі збільшенням вмісту нано-діоксиду цирконію та наносрібла. Ця робота показує, що підготовлені зразки можуть бути використані для стоматологічних застосувань.

Key words: polymethyl methacrylate, ZrO_2 nanoparticles, Ag nanoparticles, hardness, compression test.

Ключові слова: поліметилметакрилат, наночастинки ZrO_2, наночастинки Ag, твердість, тест на стиск.

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1. INTRODUCTION

Polymethyl methacrylate (PMMA) is the majority universal denture support material [1] owing to its aesthetics, biocompatibility, and stability in the mouth environment, exact fit, little cost, repair possibility, and fabrication simplicity. However, PMMA has weak mechanical properties that frequently consequences in denture support fractures. Like denture fractures, it may happen in the patient's mouth regularly at the midline of the denture foundation through mastication [2].

Nanomaterials are known of better properties compared to the conventional ones. When nanomaterials are taken part in the matrix of polymer like fillers [3–6], these materials have properties of together elements to develop new mechanical and optical properties of nanocomposites [7]. Among these, zirconium oxide (ZrO_2) nanoparticles are frequently used mechanically to strengthen polymers and get better the strength of the reinforced PMMA medium. Good quality bond and uniform dispersion of nanoparticles inside the resin matrix enhance the bending properties of the nanoparticles–polymer composite [7].

Silver nanoparticles (AgNPs) are one of the main generally used nanoparticles in this range, because of their antimicrobial activity as well as electrical conductivity and catalytic properties. The silver nanoparticles have revealed antimicrobial property against many microorganisms such as *E. coli*, *Staphylococcus epidermidis*, *Staphylococcus eureus*, author for correspondence *Candida albicans* and *Streptococcus mutans* and very little toxicity against human and animals [8]. In this paper, the addition of zirconia and silver nanoparticles is used in order to improve the mechanical properties of PMMA in dental applications.

2. EXPERIMENTAL WORK

The samples were synthesized by casting method with the use of mixtures of polymethyl methacrylate, nano-zirconia (nano-ZrO_2) and nano-silver (nano-Ag) powders. The mixtures composed of polymethyl methacrylate with weight percentages 0, 0.75, 1.5, 2.25 for nano-ZrO_2 and nano-silver. Nano-zirconia and nano-silver was added with same weight percent to polymethyl methacrylate. The structural property of (PMMA–ZrO_2–Ag) nanocomposites was tested by photomicroscope. The hardness of the samples was measured by using the TH-717 device. The compression test was measured by using the Cube and Cylinder Compression Machines Ct340–Ct440 apparatus.

3. RESULT AND DISCUSSION

Figure 1 shows the surface morphology of the (PMMA–ZrO_2–Ag) nanocomposites with and without different concentrations of silver and zirconia nanoparticles' content. The microstructure of the (PMMA–ZrO_2–Ag) nanocomposites' samples shows the distribution of Ag and ZrO_2 nanoparticles in polymethyl methacrylate; nanoparticles of Ag and ZrO_2 begin to agglomerate in PMMA as shown in Fig. 1, *d*.

The hardness test was applied to the specimens before and after addition nano-Ag and nano-ZrO_2 to PMMA. The hardness of samples increased with increasing addition of ZrO_2 and Ag nanoparticles to PMMA, and then decreased at 2.25%, as shown in Fig. 2.

The increasing in hardness of samples is due to the hardness of zirconia [9] and sliver nanoparticles. The agglomerated nanoparticles can perform as stress concentrating centres in the medium and affect harmfully on mechanical properties of the polymerized compound [10]. In addition, the problematic includes in the incorporat-

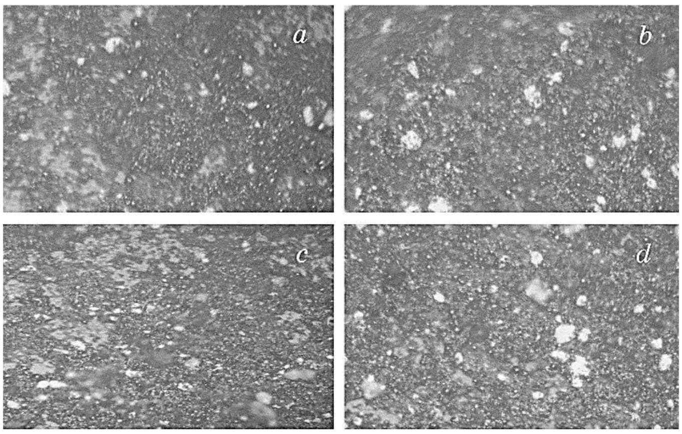

Fig. 1. The microstructure of (PMMA–ZrO_2Ag) nanocomposites at (*a*) 0 wt.% Ag–ZrO_2; (*b*) 0.75 wt.% ZrO_2–Ag; (*c*) 1.5% wt.% ZrO_2–Ag; (*d*) 2.25 wt.% ZrO_2–Ag.

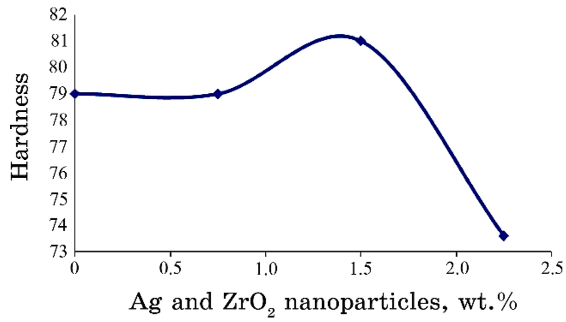

Fig. 2. Variation of hardness for PMMA with different concentrations of ZrO_2 and Ag nanoparticles.

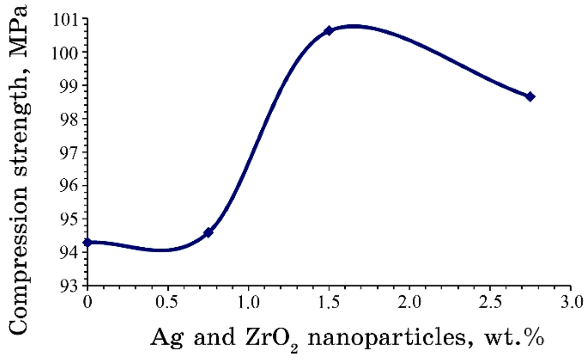

Fig. 3. The relation between compression strength and different addition of weight percent for the ZrO_2 and Ag nanoparticles in PMMA.

ing nanoparticles into acrylic resin which lack the chemical bond between inorganic materials like sliver nanoparticles and PMMA [11, 12]. Figure 3 explains the compression strength of the samples and the addition of nano-ZrO_2 and nano-Ag powders. The compression strength of the samples gained with increasing addition of nano-Ag and nano-ZrO_2 and then decreased at 2.25 wt.%. The increasing in compression strength of the specimen is attributed with arising of the surface area and good mechanical properties of Ag and ZrO_2 nanoparticles, while the decreasing in compression strength may be retain to agglomerate formation.

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