RESEARCH PAPER

Preparation and Enhancement of (Hydroxyapatite/Bioactive glass) Composite by Mg Nanowires for Dental and Bone Implants

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ABSTRACT

In the subject of the research under the current study, a composite resin consisting of (30% bioactive glass with 70% hydroxyapatite) was used, and this is compatible with the components of the bone tissue of the tooth. After many studies haveproven the failure of the use of inert materials in the composition of the composite resin used in orthopedic applications and dental implants, the using of bioactive materials such as bioactive glass has been resorted as it has proven its bond with living tissues in addition to having an anti-bacterial property on the one hand, and on the other hand it is a compatible material biologically. In this study, some mechanical and physical properties of the composite resin were improved by adding weight percentages of a nano-material, magnesium nanowire, at rates (0-4) %. Some of the techniques that were used, such as X-ray diffraction examination to find out the components of the composite resin from bioactive glass and hydroxyapatite, in addition to the scanning electron microscope examination and through it the good distribution of magnesium nanowire material was observedin the composite resin, where the examination shows the homogeneous distribution and full of pores in the composition. By analyzing the results of the research, it can be observed that the compressive strength property improved at 4% magnesium nanowire (208 MPa) and (50 MPa) at 0% magnesium nanowire. Also, an improvement in the wear rate, as the weight loss values decreased with the increase in the percentage of the nano-added material, and the best value was at 4% magnesium nanowire. As for the thermal conductivity property, its best values were at the highest value of the addition of the strengthening material, and all values were within the permissible range for clinical dental implant applications. As for the examination of the micro-hardness, it was decreasing as the values of addition increased until it reached the lowest hardness at 4% and the highest values of hardness at 0%, which is also within a close range and is allowed in dental implant applications.

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INTRODUCTION

Dental disease, caries, decay, crushing or breaking part of it prompted the development of materials that could replace dental. Many materials were produced and used in dental implant to manufacture complete teeth, restore part of the tooth, or fillers to repair holes in the tooth. However, since the lifespan of these materials generally ranges from 10 to 20 years and human life expectancy hasincreased, researchers

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are working on developing these materials to increase their lifespan within the human body [1].

Hydroxyl apatite is a naturally occurring form of calcium apatite. It has the chemical formula $(Ca_5(PO_4)_3(OH)$, but it is usually written as $Ca_{10}(PO_4)_6(OH)_2$ and it is white in color. About 50% by volume and 70% by weight of human bones and teeth are made of hydroxyapatite, which is known as bone mineral. Hydroxyapatite can be produced naturally, such as coral [2].

The mechanical properties of hydroxyapatite are poor, so it cannot be used directly in dental and orthopedic applications. Therefore, this study was conducted for the purpose of improving the properties of bioactive glass and hydroxyapatite composites and using them in orthopedic applications [3].

Bioactive glass is bio-glass and surface-reactive ceramic materials and it is referred as Bioglass®. As aresult of the biocompatibility and bioactivity of these materials, they were used as implant devices in the human body to repair and replace diseased or damaged bones, the most important of which is teeth. Mostof these materials are silicate-based glass that is biodegradable in body fluids and can act as a means of delivering ions that are beneficial for healing [4].

Bioactive glass is used with other materials in artificial bone and dental applications such as biphasic calcium phosphate, hydroxyapatite, calcium sulfate), as it is the only glass with anti-infective and antiangiogenic properties [5]. At the beginning, many researchers are developed the first biologically active material, 45S5 bioactive glass (Bioglass ®). This biomaterial not only causes any inflammatory response in the body, but also forms strong bonds with bones and soft tissues, improving implant stability and extending its durability. This material is a bioactive glass that belongs to the system [6]. A strong interface between biomaterials and tissues is established through chemical reactions that occur on the surface of the bioactive glass, concomitant with biological events that lead to the formation of a calciumphosphate nano-hybrid complex synthesized by biological molecules [7]. Nanowire in nanotechnology are defined as a body as a complete unit in terms of its transmission and properties, its diameter ranges from 1 to 100 nanometers and the length to diameter ratio is more than 10 [8]. Similar to the nanoparticles, the nanoparticles range between 1 and 100 nanometers in addition to a small size distribution. Sometimes nanoparticles do not have the same size-related properties, which may differ significantly from those that can be observed in microstructure. Currently, Nano-additions researches are focused on the intense scientific interest, due to the diversity of potential applications in biomedical fields and improving the properties of materials with small additions to produce nanocomposites. In this study, Nano-rods were used to reinforce composites of Hydroxyapatite/Bioactive glass which are used as dental implants [9].

MATERIALS AND METHODS

The first stage is manufacturing the base composite material (Hydroxyapatite/Bioactive glass), as the ceramic composite material consisting of hydroxyapatite with bioactive glass (Table 1) was manufactured by powder technology, which includes mixing the components together using the mixtureat a speed of 80 revolutions per minute for 3 h with the addition of acetone to reduce the heat generated from friction between the grains, then the samples were pressed into molds by pressing under a pressure of 160 MPa and then sintered in a furnace at a temperature of 850°C for 8 hours [10].

The second stage is manufacturing the nanocomposite materials (Hydroxyapatite/Bioactive glass) with magnesium nanowires (45 nm in diameter and 2 µm in length) by mixing with acetone using mixture(80 rpm for 4 hours), after that the samples are formed by pressing at (20 MPa) and then sintering in the oven at (450

Table 1. Chemical compositions of using materials

Bioglass: (45% wt SiO_2 , 6% wt P_2O_3 , 24.5%wt Na_2O, and24.5% wt CaO).
Hydroxyaptite: $Ca_{10}(PO_4)_6(OH)_2$
Magnesium nanowires: Mg NWs

degrees Celsius) for one hour.

Testes and Examinations

X-Ray Diffraction: X-ray diffraction exam was used to study composition of the samples.

Microhardness: Microhardness Vickers test was achieved according to (ASTM E92-82) by Vickers tester. This apparatus was used to measure the hardness with (1000 g) load and holding time of (20 seconds) to the surface of the specimen using a standard (136°) Vickers diamond pyramid indenter combined with an optical microscope [11].

Thermal Conductivity: The thermal conductivity examination was achieved for the its compositesto show the effect of Mg nanowires on the thermal conductivity using hot disk device (Thermal constant analyzer type Tps 500, made in Czech) [12].

Compressive strength: The compression test was done according to (ASTM (D95-85)) for the samples at speed of (1 mm/min) using universal testing machine with the maximum load of (100KN) [13].

Wear Test: Pin-on-disc test technique is used for investigating sliding wear. The speed of steel discwas constant (600 rpm) and the load that used in this test was (2 – 20) N for 10 min [12].

Scanning Electron Microscope (SEM): SEM uses a focus beam of high electrons energy to producea variation of signals at the surfaces of the specimens. The signal reveal information about the samples including external morphos, crystalline structure, orientation, chemical composition of the sample.

RESULTS AND DISCUSSIONS

X ray diffraction

Fig. 1 shows XRD patterns over (10 ° – 90 °) at a scan rate of (3 ° min) for nanocomposite. According to cards No 27-0784 No. 27-1064, No. 9-432 and No.80-1296, No. 02-0961, a phases $Na_2Ca_6(Si_2O_7)(SiO_4)$, Na2Si2O7 and $CaSiO_3$, structure appears in the (Bioactive glass- Hydroxyapatite / Mg nanowires nanocomposite) [12].

Microhardness

The current study proved that the best values of hardness are at 0%, that is, when the nanocomposite material is free of reinforcement ratios and is composed of bioactive glass with hydroapatite. However, it is noted that the hardness values of the composite resin are within the permissible range in dental implant applications [13]. The main reason that led to the decrease in the hardness values is that the additive material Mg nanowire, which is magnesium nanowire, has a hardness much lower than that of the composite resin [11].

Through the hardness test, the hardness of the same sample was measured in different regions, to be an indication of the homogeneity of the distribution of the nanowires within the matrix, and it was found that the hardness values of the same sample for different regions are close, which indicates the homogeneity of the distribution of the reinforcing material and not agglomeration [12].

Thermal Conductivity

when adding a conductive material, whether of a nano or micro size, this leads to an improvement and an increase in the thermal conductivity values of that material. We note in this study that

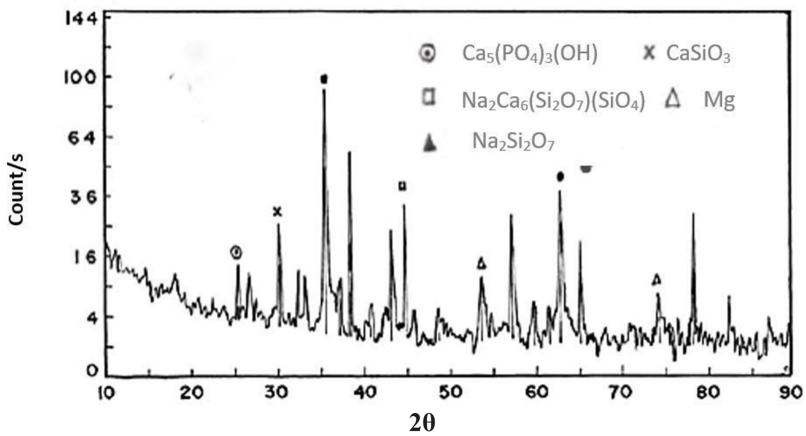

Fig.1. X-Ray Diffraction patterns of (BAG/HA/MgNWs) nanocomposite.

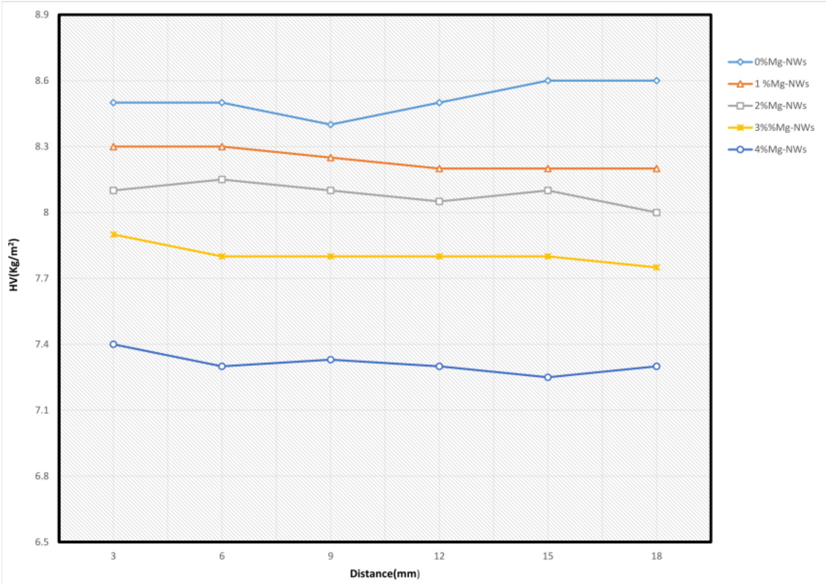

Fig. 2. Effect of Mg NWs addition on hardness of BAG/HA with different distance.

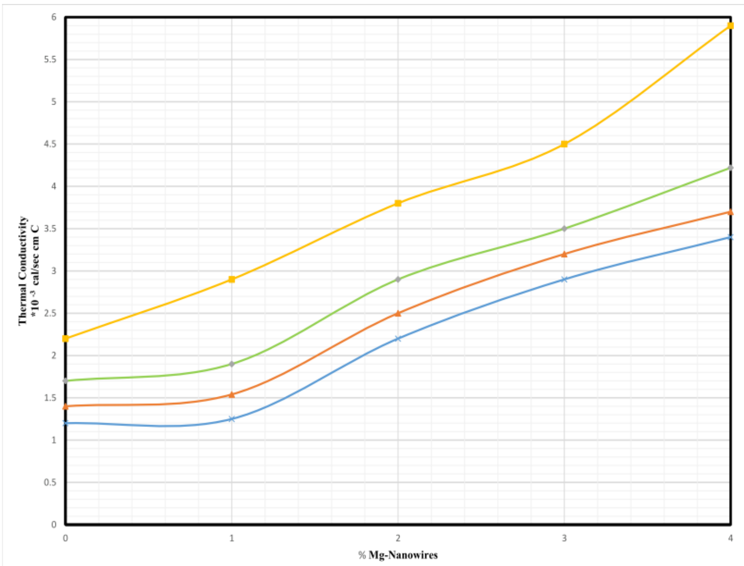

Fig. 3. Effect of Mg NWs addition on thermal conductivity of BAG/HA Composite.

the addition of a thermal conductive materials (magnesium nanowire) to the composite resin consisting of bioactive glass and hydroxyapatite, led to improvement in the thermal conductivity values of the resin. It can also be noted that this increase in the thermal conductivity values of the compound is within the required range of work in dental implant applications [10].

Compressive strength

In the current study, we notice a clear and gradual increase in the compressive strength values of the resin consisting of a composite of bioactive glass with hydroxyapatite in fixed weight ratios and reinforced with a nano-material in the form of nanowire, which is magnesium nanowire. This compound was usedwith dental implants [11].

The reason is due to the first of the presence of internal pores in the structure of resin composite, and these pores led to the weakness of the mechanical properties of the composite resin, including the function of compressive strength. Here comes the role of nanowire of magnesium to fill these pores andthus result the composite resin

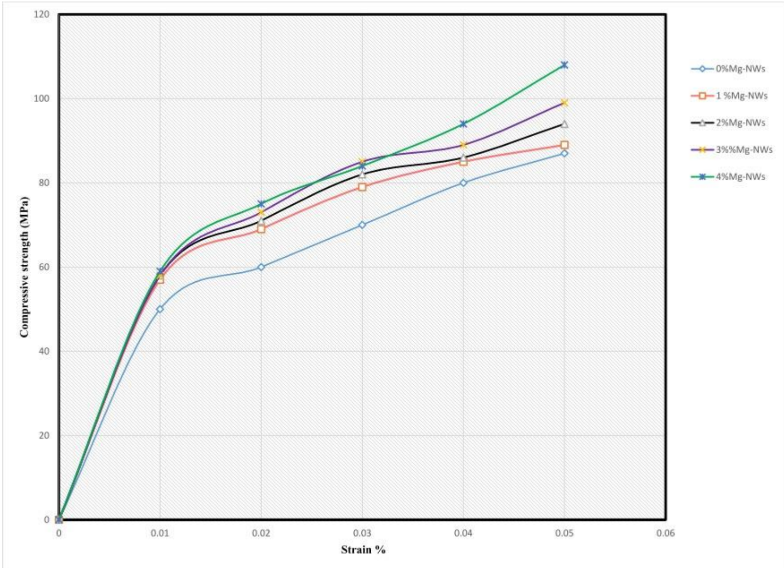

Fig. 4. Effect of Mg NWs addition on compressive strength of BAG/HA Composite.

into a strong composition and increase its density and this helped to impede the movement of crystal levels, which led to an increase in the compressive strength values. Theadditive of bioactive glass to metal and alloy enhancement some mechanical properties [12].

The highest compressive strength was at (4% of magnesium nanowire with nano-composite) comparedto the others samples.

Wear resistance

In the diagram below, which shows the relationship between the values of loss weight and the values of the loads applied to the composite resin, we note that the values of weight loss decrease as the percentage of magnesium nanowire increase for the composite resin consisting of bioactive glass and hydroxyapatite, and the best values were at a value of 4 % of added nanowires, that proven by added nanomaterial

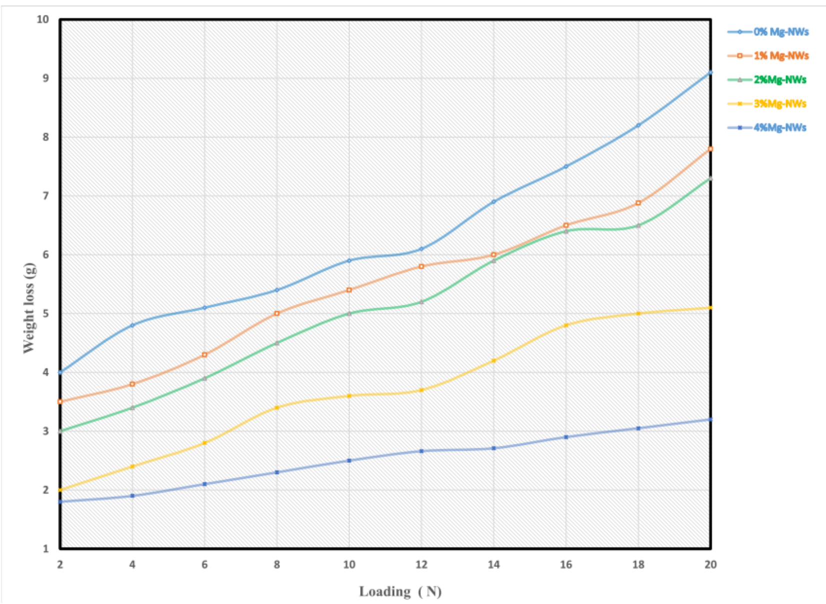

Fig. 5. Effect of Mg NWs addition on weight loss BAG/HA Composite.

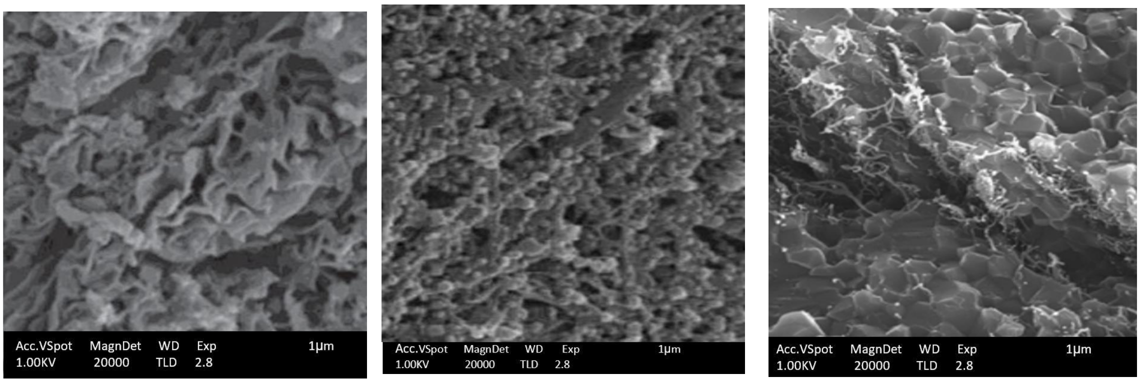

Fig. 6. Effect of Mg NWs addition on the microstructure of BAG/HA composite.

such as CNT to Ti and its alloy [12].

The reason is that the added nanowires act as a network linking the components of the nanocomposite material on the one hand, and on the other hand, it worked to fill the internal pores in the composite resin,which led to a reduction in the rate of weight loss.

Scanning Electron Microscope

We note from the following forms of scanning electron microscopy examination in Fig. 1, which represents the model for the composite resin without adding a nano-material. We note the presenceof very clear pores on the surface of the sample and extending inward. As for Fig. 2 and 3, it represents the nanocomposite material with nano addition, where we notice a decrease in the appearance of pores due to the penetration of the magnesium nanowire inside the compound resin and filling those pores. We also observe the homogeneous distribution of magnesium nanowire through the microstructureof the nanocomposite.

CONCLUSIONS

The X-Ray Diffraction analysis showed a rapid crystallization process and a phases $Na_2Ca_6(Si_2O_7)(SiO_4)$, $Na_2Si_2O_7$ and $CaSiO_3$ structure appeared in the nanocomposite matrix. The reinforcement by Magnesium nanowires led to decreasing in hardness of bioactive glass nanocomposite from (8.9 to 7.4 Kg/mm^2). The reinforcement by Magnesium nanowires led to gradual increase in the compressive strength of a nanocomposite of bioactive glass with hydroxyapatite. The reinforcement by Magnesium nanowires led to increasing in thermal conductivity of glass ceramic composites. The values of weight loss decrease as the percentage of magnesium nanowire increase for the nanocomposite resin consisting of bioactive glass and hydroxyapatite. In SEM noted decreasing in the appearance of pores due to the penetration of the magnesium nanowire inside the compound resin and filling those pores we also observe the homogeneous distribution of magnesium nanowire through the microstructure of the nanocomposite.

CONFLICT OF INTEREST

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

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