Mechanical and Physical Properties of PMMA Reinforced HA-MgO Nano-Composite

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Abstract. In this paper, a combination of a ceramic mixture with a polymer was developed to be used as a substitute for damaged bones or teeth. Overlays were prepared using the manual mixing method, followed by the use of ultrasound technology to ensure uniform distribution of the powder within the polymer. The polymer (PMMA) is supported with a ceramic powder (HAMgO) prepared using an effective mechanical mixing method and component than hydroxyapatite (HA) is a principle inorganic component of human hard tissues such as teeth and bones and metal nanoparticle magnesium oxide (MgO), which represents the additive to the polymer (PMMA). The percentage used for reinforcement, starting from (1% - 4%). The results of the tests showed mechanical corrosion or the so-called where wear is decreased for the reinforced polymeric composites as the corrosion rate decreased to less than half at 4%. Likewise, the results of the particle hardness examination showed a successive increase in the percentages compared to the polymer base material. The results of the durability of compressibility and Young's modulus showed a direct increase with the increase in the percentages of the added ceramic powder.

Key Word: Nano-composites, Polymer, PMMA, HAMgO, Compression strength, Young modulus.

1. Introduction
Polymeric composites have unique properties that qualify them to work in all fields, including industrial, medical, and engineering, in addition to their use in military applications and in the manufacture of spacecraft [1, 2]. Many researchers in this field were interested recently in this century in developing and producing polymeric-based compositions that act as materials that have the ability to withstand various mechanical stresses and have the ability to operate in harsh environmental conditions [3, 4]. In light of this, many researchers were able to prepare polymeric nanoparticles that are used in bone and skeletal alternatives as well as used in the manufacture of teeth and their permanent fillings [5, 6]. These prepared composites underwent high physical and mechanical conditions and showed great success in tolerating scratching and wear and resistance to fracture compression [7, 8]. The polymers are histologically compatible with the organism are the most important characteristics in the formation of nanocomposites in this field and the most important medical polymers are (PLA, PMMA, HDPE, PVA, as well as biochemical materials are one of the pillars of the preparation of polymeric composites for replaced body parts use, such as Al, O, ZrO2, TiO2, CaO, HA, MgO [9, 10, 11]. These composites have specific properties that have the ability to withstand mechanical stresses and have the ability to resist bacteria and fungal. Most ceramic
materials are materials compatible with body tissue and bonding, especially if they are in the nanoscale [12, 13]. Many researchers studied at AH the field where the researchers prepared polymer composites supported binary ceramic powder from and they obtained promising results in improving mechanical properties [14].

The aim of the research is:
- Prepare the binary bio-ceramic powder (HAMgO).
- Prepare polymer nanocomposite (PMMA-HAMgO)
- Study physical properties (density, hardness, compressive strength, Young's modulus or modulus of elasticity, and wear) of (PMMA-HAMgO).

2. Materials and preparation of polymer nanocomposite
The materials were diagnosed and their ability to work in this field was also determined, and then was prepared. The polymer polymethyl methacrylate (PMMA) was purchased; it is in two parts the first is a liquid called the monomer (methyl methacrylate) and the second part is the powder with a purity of 99.8. While with regard to ceramic powders are hydroxyapatite HA with a purity of 99.995, and magnesium oxide MgO with a purity of 99.998, has been stated. The composite was prepared using liquid mixing and ultrasound technology to ensure a homogeneous distribution between the polymer and the binary powder. Then the models were formed according to the measurements approved in the examination.

3. Experimental part
The PIN-ON- DISC system was used to calculate the sliding wear and tear wear rate of the compounds. Models were created with dimensions of 1 cm in diameter and 3 cm in length. Using the following equations, the final wear rate [15]. Was calculated:

\[ W_r = \frac{\Delta M}{S_D} \] wear rate

\[ \Delta M = M_1 - M_2 \] the weight loss

\[ S_D = \pi.N.D.T \] sliding distance (m)

Where:
N: 2950 (riv/min)
D: Routing distance = 6cm
T: Sliding time (min)

\[ W_V = \frac{\Delta M}{\rho} \] volume wear

\[ W_{Coff} = W_V . H_V / L . S_D \] Coefficient wear

\[ \rho \] Experimental density (g/cm³)

\[ H_V \] Number Hardness (MPa)

With regard to density, the Archimedes method was used to calculate the density of nanocomposites as well as the dimensional method to ensure the accuracy of the calculation. Vickers hardnes device was also used to calculate the surface micro hardness of the superposition’s where the results were recorded directly from the system in (Mega Pascal, MPa) units and using a time of 20 seconds and a force of 0.5 Newton where the equation was used:

\[ H_V = 1.8544 \sqrt{F} \] (MPa)

With regard to the compression test, the results were obtained by the system, called the universal machine, where the models were formed as cylinders with dimensions of 2cm x2cm.

4. Results and discussion
4.1 Physical properties results
Table (1) and Figure (1) show a summary of the practical results of the physical properties that were performed for the prepared models, where the values of the practical intensity that was calculated by the Archimedes method and also was confirmed using the dimensional method. The results showed a significant improvement in the values of practical density with a direct increase with the percentage of
additives. The reason is due to the closing of pores and the stacking of particles between the components of the mixed materials. The other reason is due to the high density of the additive and to the high surface area and the nano-scale of this is illustrated in Figure 1. All other properties, such as particle hardness, compressive strength, young modulus (elastic modulus), depend mainly on the density values for their structural association with these properties. The hardness values showed a significant improvement and a significant increase in the values of nanocomposites compared to the base material polymer. This is due to the cohesion between the molecules, the substances formed for the compounds, as well as due to the high density possessed by the nanocomposite as shown in Figure (1). An important test for studying the physical properties is calculating the durability of compression, the results of compression durability show a clear improvement in the durability values of the compounds compared to the base material. This is due to the nanomaterial in transferring stress and distributing it in a way that reduces the failure in the model and this is clearly evident in the Figure compression strength. In Figure 1 of the modulus of elasticity, the great improvement in the values of the modulus of elasticity is evident. This indicates the resistance of the material to compression to a certain extent without any breakdown. All these results related to properties are consistent with the reference [16].

![Graph a](image1.png)

![Graph b](image2.png)
Figure 1. Mechanical Properties of the prepared components (a) Density, (b) Hardiness, (c) compression, (d) young's modulus. All these investigations were done versus weight percentage of samples.
Table 1. Practical results of the physical properties of nanocomposites PMMA \ HA-MgO.

| Samples | Density (g/cm$^3$) | Hardness (MPa) | Compression strength (MPa) | Young's modulus (MPa) |
|---------|-------------------|----------------|---------------------------|-------------------|
| 0%      | 1.144             | 36.2           | 77.4                      | 877               |
| 1%      | 1.198             | 46.9           | 102.4                     | 1300              |
| 2%      | 2.22              | 65.5           | 111.5                     | 1600              |
| 3%      | 2.28              | 89.7           | 122.6                     | 2200              |
| 4%      | 2.32              | 100.5          | 135.3                     | 2800              |

4.2 Wear properties

Table 2 and Figure (2) show a summary of the practical results of the triple properties of the prepared samples. A screw-on-disk device was used to calculate the dry mechanical corrosion rate of the nanocomposites and the dominant model. The results showed the calculation of the dry sliding wear factor and a clear decrease in the amount of abrasion of the nanocomposites. This is due to the improvement of the outer surface of the samples supported by the nano-powder, which cause to blocking the pores and voids and strengthening the bonds between the components of the supported sample compared to the unsupported substance (polymer). Therefore, such a work can be used in the dental industry and damaged bone replacement, because these prepared nanocomposites have a high resistance to wear and wear, and this is consistent with the reference [16]. In order to check the practical results of calculating the dry mechanical corrosion rate, the volumetric wear rate was calculated to ensure the accuracy of the calculation. It was included in the calculation of the mechanical corrosion rate, the practical intensity of the prepared models. Figure 3 shows volumetric wear behavior and we note the significant decrease in the volumetric corrosion values of nanocomposites compared to the base material (Polymer).
Figure 3. Volume wear rate versus weight percentage of samples.

Table 2. Wear values at 10 min of PMMA-HAMgO.

| Samples | M_1(g) | M_2(g) | ΔM(g) | W_R (g/cm) × 10^{-6} | W_V (cm^3) |
|---------|--------|--------|-------|-----------------------|-------------|
| 0%      | 3.447  | 3.246  | 0.201 | 0.262                 | 0.127       |
| 1%      | 3.778  | 3.677  | 0.101 | 0.0575                | 0.0267      |
| 2%      | 3.799  | 3.712  | 0.087 | 0.0215                | 0.0054      |
| 3%      | 4.021  | 3.998  | 0.023 | 0.0161                | 0.0039      |
| 4%      | 4.134  | 4.125  | 0.009 | 0.0035                | 0.0008      |

5. Conclusion
A significant improvement in all the physical properties of the nanocomposites was occurred. This is due to the great correlation between the nanocomposite within the polymer molecules, which gives it strength, durability, hardness and an increase in stacking. The considerable decrease in the scaling amount of nanocomposites to rates was obtained that do not nearly affect the weight and size of the samples is due to the high surface area of the nanocomposite and to the nanoscale used.

6. References
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