Mechanical Properties of (PMMA/CaTiZrO5) the Biocompatible

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Abstract-- In the present study, composites have been prepared with basis polymers reinforced with triple system of bio-ceramic (CaO, TiO2, ZrO2). The percentages of the weight have been (0%,2%,4%,6%,8%). The method of mixing the manual fluid and the ultrasound technique to distribute the powder pre-prepared within the polymer to obtain the desired mechanical properties has been suitable for this purpose. Mechanical tests have been performed to determine the efficiency of the composites performance, the Included (Impact strength, hardness and wear resistance). The results have shown a significant improvement in the values of the impact energy and the hardness of the particulate as well as the high resistance to wear the composites compared to the base material. The results have been interpreted according to synthetic tests for the powder (X-ray, SEM, EDX).
Keywords: Bio-ceramic, Nanocomposite, Wear Resistance,PMMA.

1. Introduction

Recently, polymers have been increasingly used as biomaterials, especially for dentistry and bone restoration. The researchers aim to improve the properties and performance of polymers, prove that the materials contain very good mechanical properties, and have self-healing capabilities and stability under extreme conditions using the innovations of synthetic materials design and treatment. Nowadays, polymers and their composites are widely used in many engineering applications [1, 2].PMMA has been used in dental applications since 1937[3]. It is one of the most suitable polymers to be used in dental applications as compared to many available polymers. Because of its easy configuration and color adaptability to the excellent aesthetic properties, PMMA is suitable for synthetic teeth [4].However, PMMA shows pure properties of poor fatigue, chemical deterioration, and low mechanical strength. Different methods can be used to improve the mechanical and physical properties of PMMA. One of these methods is the use of appropriate fillings [5].Using nanotubes of different sizes and shapes, polymer matrices have been strengthened to improve polymer properties [6,7].Titanium dioxide (TiO2) is currently widely used as a pigment in paints, ointments, toothpaste, etc,Tolou1 et al. [8].Bio-TiO2 has also been used to improve the mechanical and physical properties of host materials [9]. It has recently been reported that TiO2 nanoparticles improve biological compatibility and they can be used as a dental amalgam. As well as for the manufacture of 3D printed dental suit, PMMA has been enhanced with nanotubes TiO2 to increase antibacterial activity [10]. In a recent study, it is stated that a poly (methyl methacrylate) compound contains different amounts of ZrO2 for biomedical applications. It has an impact on bending strength, fracture hardness, and it is a reliable dental base material [11]. In a study that examined the effect of Nano-hydroxyapatite particles on mechanical properties of PMMA / Nano-composites, it was observed that corrosion rate decreased by increasing nanoparticles in content [12]. Both Nano-composites were analyzed for their structural, thermal and mechanical properties and benchmarked against pure PMMA sample. Their validity as potential dental appliance material was assessed. Mathematical relations were used to calculate absorption energy, material toughness, and rate of wear according to the following Equations:

$$Eg = 75\,.\,(\cos\beta\,.\cos\alpha) - - - - - - - - - (1)$$

$$K_c = \sqrt{(Is - E)} - - - - - - - - - - - - - - (2)$$

Where:

Eg, is the absorption energy(joule) and(β , α) : angle used in the test.

$\boldsymbol{K_c}$: material toughness (KJ-N)^1/2), Is: impact strength and E : elasticity coefficient (Gpa)

$$\mathrm{Wr} = \Delta m / S_D \; - - - - - - - - - (3)$$

$$S_D = \pi.\omega.\mathrm{D.t} - - - - - - - - - - (4)$$

$$W_v = \frac{Wr}{\rho} - - - - - - - - - - - - (5)$$

$$W_{coeff} = \frac{W_v\,.\,H_v}{S_D\,.\,L} - - - - - - - (6)$$

Where:

Wr: wear rate, $\boldsymbol{\Delta m}$: difference weight loss of the sample before and after the wear test (gm.), $\boldsymbol{S_D}$: sliding distance (cm),ω : number of revolutions of the rotating disc (rev./min), D: circular sliding diameter (cm), t: sliding time (min),

Wv:Wear volume (kg/m³), $\boldsymbol{\rho}$*:* density(g/cm²), *L*: (load) applied on the sample (Newton),and $\boldsymbol{W_{coeff}}$: wear coefficient(g/cm).

2. Experimental work:

A. Nanocomposite preparation (CaTiZrO5):

Raw materials have been purchased to prepare enhanced composites, Biocompatible (CaTiZrO5), and TiO2 particles nanoparticle size: 25nm Purity: 99.8%, Chengtou-Stabilized Zaxonium Oxide Nanoparticles / Nanopowder (ZrO2-3Y, 30 (99.8% nm) (USA) and calcium oxide CaO Nanoparticles (Laboratory preparation). In order to obtain an interactive form of CaO in vitro, from eggshells after creasing and crushing to semi-powders and then burning it into the reaction furnace at 450 °C, 700 °C, 900 °C, CaCO3 powder and decomposition in an electrical furnace at 1100 °C were obtained. In the present study, PMMA is selected as a base material. Composites have been prepared using the manual fluid mixing method and the ultrasound technique to well distribute CaTiZrO5 powder; A mixture of nanomaterial (CaO, TiO2, ZrO2). In the composites Biocompatible (PMMA / CaTiZrO5), PMMA has been improved with the nanoparticle powder of (CaTiZrO5) in the weight ratio of (0%, 2%, 4%, 6%, 8%). Both nanometric composites have been analyzed for their structural and mechanical properties and measured against a pure (PMMA) sample. Then, the samples have been formed according to the standard specifications of the required tests after the heat treatment of the samples at 70 °C for 12 hours and leaving them for 15 days at room temperature for the completion of polymerization and acquisition of the required physical properties. Mechanical tests have been carried out by the rate of wear, hardness, and compressibility as well as the impact strength of all models and the same standard conditions. The image of the electron microscope (SEM) shows the particle size of the overlapping material with magnification limits (50 k) as shown in figure (1).

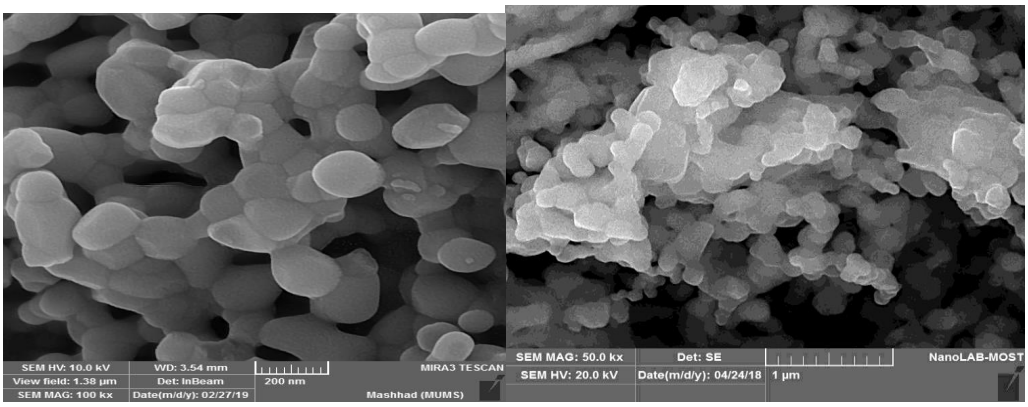

Fig. (1): Image of Scanning Electron Microscope (SEM) for the composite (CaTiZrO5).

To determine the proportion of reaction materials the atomic dispersion spectroscopy (EDS) was used in terms of the energy density shown in Figure (2).

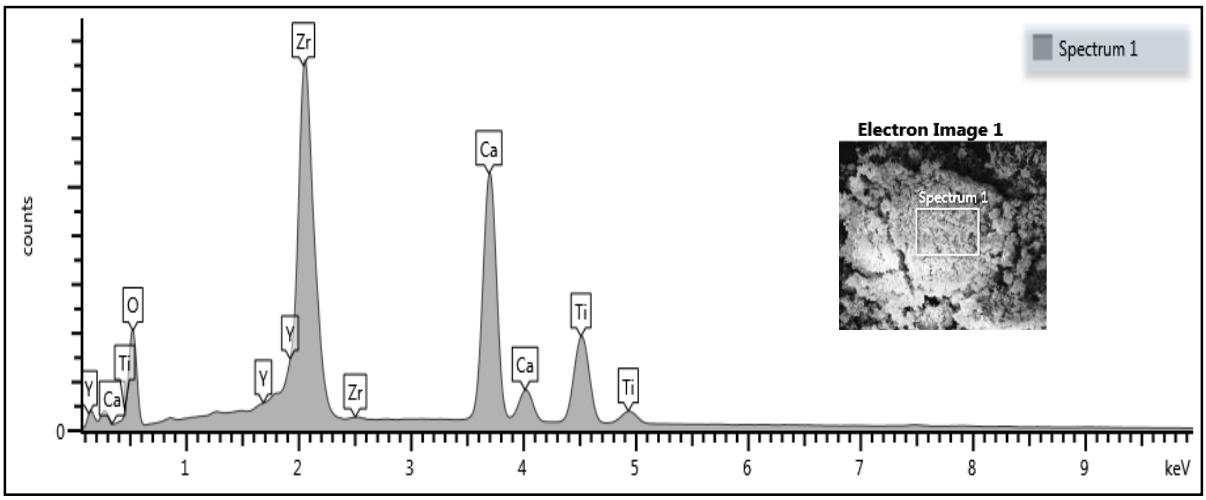

Fig. (2): the atomic dispersion spectroscopy (EDS).

Table (1) shows the information obtained from the x-ray examination of the prepared powder at 1200 ° C, and Figure 5 shows the phases formed to be the highest peak at the angle (2Ø=30.0517) of the compound,(ZrO2), While the peaks appear at (2Ø=30.0517) and (2Ø=30.0517) the composite made up of (CaO) and (TiO2). To obtain a composite and Phase(CaTiO3) and implicitly formed In the form of a quadratic system.

2Ø (deg)	d (A)	I/I,
30.0517	2,971	100
31.700	2.820	86
33.037	2,709	69

Table (1) shows information about the x-ray.

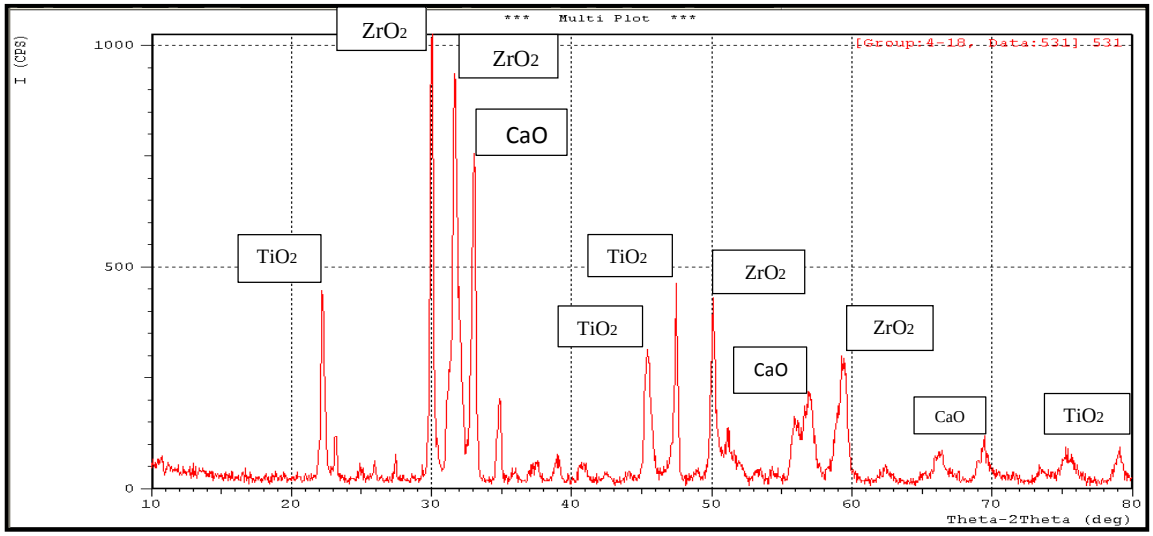

Fig. (3): XRD patterns of bioceramic powder CaTiZrO5.

3. Results and Discussion

A. Surface Hardness and Density.

The results of the test for the prepared samples were significantly improved by increasing the weight ratio of the prepared ceramic powder (CaTiZrO5) using the Vickers hardness test. The surface hardness was improved by 80% of the non-reinforced sample in the PMMA matrix. We conclude that the hardness of the ceramic powder particles improves the apparent density of the surface material in the PMMA matrix. Due to the dispersion of nanometer powder in the matrix (PMMA) and low porosity in all nanostructures.

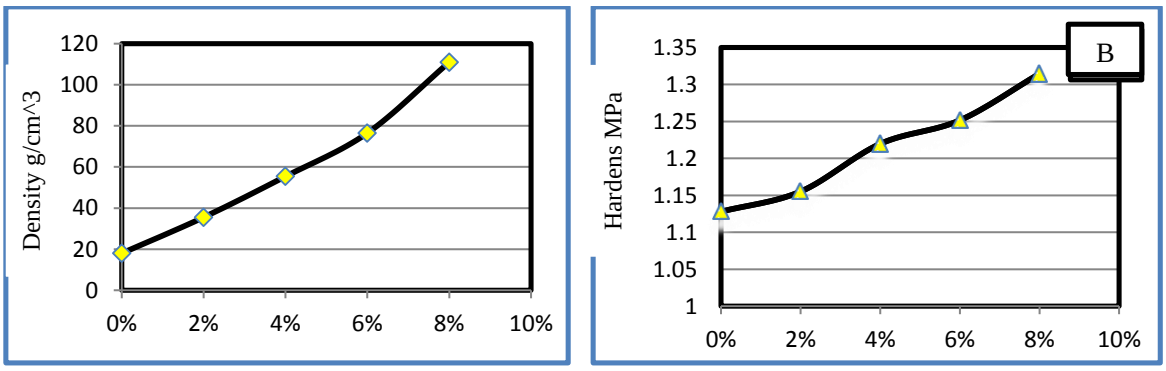

Fig.4: (A) Experimental density as function (PMMA/CaTiZrO5)
(B) Micro hardness as function (PMMA/CaTiZrO5).

B. Impact Strength.

The impact durability test is a destructive test of the samples used. The resistance test and its strength for breakage are essential for applications involving bone and tooth compensation. The test method has

been used to perform a test. Where the test samples were subjected to sudden fracture using the breaking energy of (75) joule. The lever angle used in the test apparatus is fixed to (150°) after adjusting the device and using the mathematical relationship (1) to calculate the absorption energy (Eg - joule). Figure (5) shows the absorption energy results as a function of the percentage of ceramic powder (CaTiZrO5). The resulted data showed a remarkable enhancement in the absorption energy of the prepared Nanocomposites compared to the primary material (PMMA). The reason is that the reinforced material has absorbed the pressure exerted on the sample and alleviated stress on the underlying material (PMMA) this is consistent with [13]. The impact strength results showed a significant improvement in the values of the samples supporting the ceramic powder (CaTiZrO5). The toughness of material was calculated through the mathematical relationship (2) depending on the elasticity coefficient calculated from the compressive force by (Gpa).

C. The rate of Wear.

The wear is defined as the amount of material loss from its outer surface due to the dry sliding motion between two different hardness surfaces where the less surface loses the hardness of its outer layers thanks to the generated friction and the heat produced by the high speed. The mechanism of wear is due to the collapse of the protruding protrudes from the surface of the samples to be measured due to the hardness of the disc hits (68HB). In this study, a device (Pin-on-Disc) was used to conduct the test, and the loss of mass was determined in the calculations of the rate of wear and tear according to the relationship (3).In our research, variables (time and percentage of supporting materials) were used with pressure stability (5 N), and the distance of the slide was calculated by the mathematical relationship(4) and the hardness of the disk (68HB). The test results showed three times (5min,10min,15min) to calculate the wear rate (Wr, Wv, Ws, Wcoeff) with the practical density of pre-measured samples and hardness. The figure (6) shows the wear-rate values of the variable-percentage samples with the three-times (5min,10min,15min)and the curves show a decline in the rate of wear from the time (5 min) to time(10 min) where the rate of wear turns from severe wear to steady wear in time15 min .

The wear coefficient (Wcoeff) represents the amount of accuracy in measuring the rate of wear, where it was calculated using the mathematical relationship (6). Figure (7) shows the practical results of the wear coefficient equation as a function of the percentage of reinforced powder (CaTiZrO5). Where the results showed a significant improvement in the values of wear especially in time (10min,15min) for all samples, where the value of the stability was shown to have oscillated at percentages(2%,4%) of the time (10min,15min). Moreover, increase its value by (6%) due to the durability of the samples and their high wear resistance as well as the homogeneous distribution of the supporting powder within the base polymer matrix. It is evidence of a significant improvement in this percentage of samples prepared. The graph also shows the convergence of the (6%) of time (5 min) with time (10min,15min). It indicates that this percentage is the best sample. Hence, increasing the wear coefficient of any material is proof of the resistance of the material to wear and surface erosion thanks to the dry sliding movement. The increase

in the value of the percentage (8%) at the time (5min) does not give accuracy in the results because it is the time of the beginning of the movement and that the material still show high resistance to short this period and this is consistent with [14].

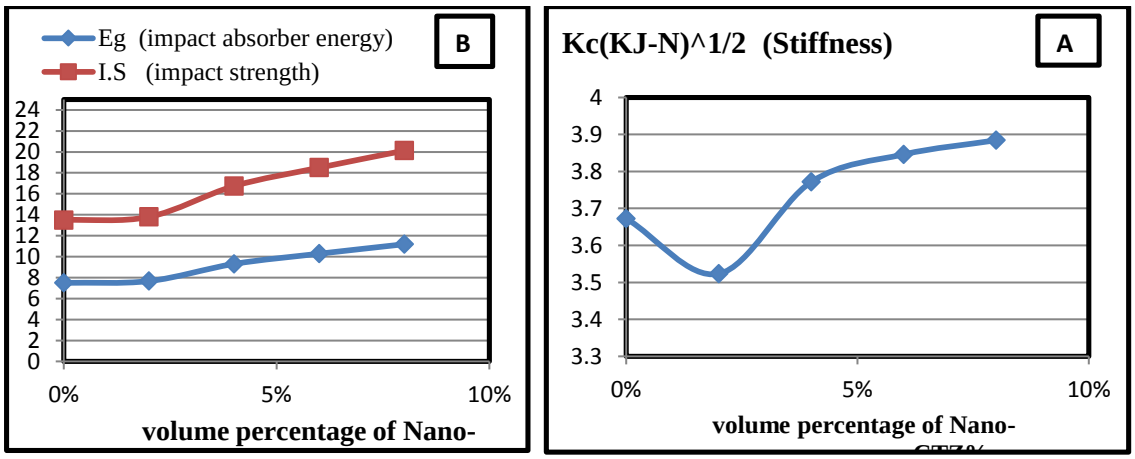

Fig (5): (A) shows the Stiffness of the supported overlays and a gradual increase with the percentage. .(B) shows the relationship between the impact absorber energy, impact strength, and percentage biomaterials.

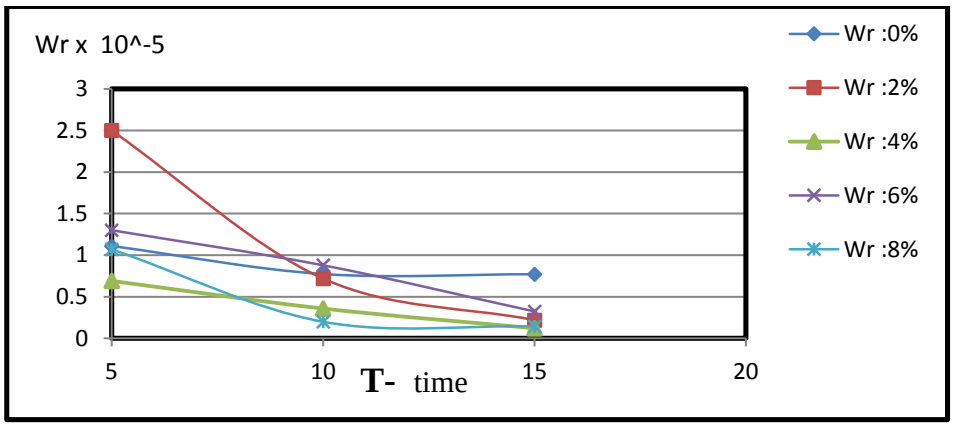

Fig. (6): shows the wear-rate values.

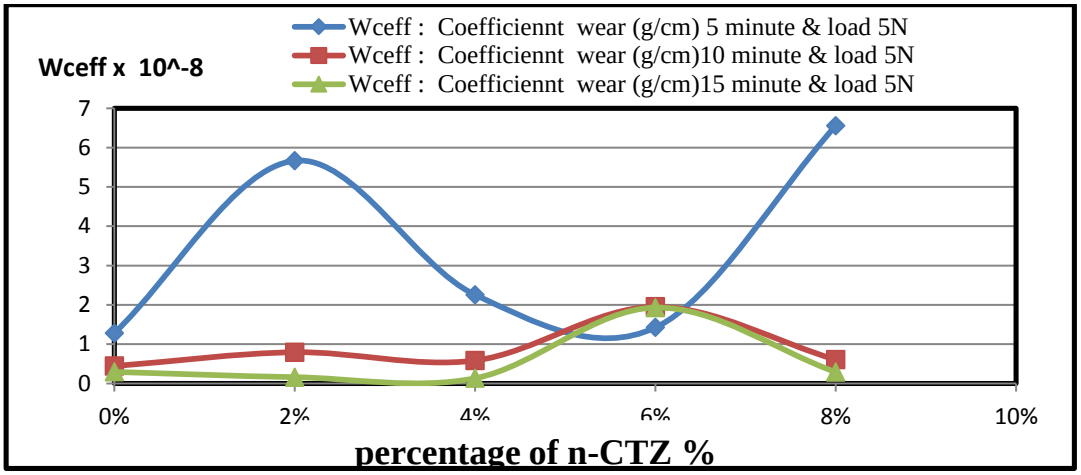

Fig. (7) The practical results of the wear coefficient equation as a function of the percentage of reinforced powder (CaTiZrO5).

4. Conclusions

The bio-ceramic nanocomposites powder (CaTiZrO5) is used in an effective mechanical mixing technique. A high homogeneity between the reacting compounds is evident in x-ray diffraction and the electron microscopy test. The practical results of the corrosion tests, the durability of the shock and hardness, and the strength of the pressure were significantly improved when the percentage of the reinforced material increased to the percentage (4%). The composite prepared can be considered as a compensatory substance for bones and teeth, which contains mechanical, aesthetic and body-compatible specifications.

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