RENFORCEMENT OF POLY(METHYL METHACRYLATE) BY $ZrO_2Y_2O_3$ NANOPARITCLES USED IN MEDICAL APPLICATIONS

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Study the effect of nano zirconium titanium yatrlum ($ZrO_2Y_2O_3$) on mechanical properties of (PMMA) has been established. The characterisations under study included tensile stress and compression, three point bending , fracture toughness and hardness. The mechanical properties are examined is found that the best mechanicl properties are at ratio 1% from ($ZrO_2Y_2O_3$) Nanoparticels to the PMMA matrix. The obtained results has given a clear perspective that $ZrO_2Y_2O_3$ affects PMMA quality significantly.

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1. Introduction

Lately,there are several studies for different materials by using Nanoscaleso as to acheivenew properties that cannot be achieved with outnon-nano[1-3] . (PMMA) is polymer of methyl methacrylate, it is produced with free-radical polymerization from the methyl-methacrylate in mass. All the Polymers are made from long molecules (macromolecule) and composed by repeating structure units typically connected with and covalent bonds. These long molecules are bonded together by hydrogen bonds [4] .Can be compounded by polymers with a variety of special fillers and common reinforcements.They can be modified to produce specific properties in more applications [5]. A polymer blend and polymer mixture is a type of a class of materials in which more polymers are blended together to produce a new material with different properties [6] .

(PMMA) is a good material because of its application in optical disks , optical fibers and lenses. When PMMA is combined with inorganic materials like SiO_2, zirconium oxide (ZrO_2) or TiO_2 at the nanometer level, the result we get is that hybrid materials have thermal stability and high strength [7-8].Homogeneous and transparent hybrid materials are prepared from PMMA and ZrO_2 , which are used as macromonomers in the grafting from polymerization of PMMA .Moreover, because the formation of nanometer miscibility and good affinity between PMMA and ZrO_2 blend composites ,PMMA/ZrO_2 hybrids have more potential for application in mechanical and optical fields[9].

Decreasing of particle size depends on the degree of agglomeration. There are many ways to lessen agglomeration such as ulta sound waves . Temperature depression allows constriction extend and strength of agglomeration of particles powder [10]. Zirconia-based ceramics have received an attention due to prospect of obtaining a nano-grained of bulk ceramic with a controllable microstructure. The discovery of a mechanism for transformation of tough zirconia to resist. Crack propagation lesds to improve the mechanical properties[11-12]. Pure (ZrO_2) has three different polymorphs, i.e., monoclinic (m), cubic and (c) tetragonal (t), phases[13].ZrO_2 has other intrinsic chemicaland physical properties, including its high toughness, strength, low wear resistance, ionic conductivity,high elastic modulus [14-16]. Zirconia is used in many applications due to the advantage of this material of good mechanical properties and the fact that this article has

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biological materials used in the formation of bone surfaces and the improvement of some types of damages [17].

Modern technologies provide powerful tools to clarify microstructures at different levels, and to know the relationships betweenproperties and structures . These new levels develop materials for more applications [18]. Polymers are commercially important amongst crystalline engineering, because it has high performance characteristics such as high good mechanical strength, ductilitymelting points, as well as excellent resistance to solvents, abrasion and fatigue [19].

The technology of blending to polymer is a way to provide materials with full set of specific properties at lowest cost, a combination of toughness, strength and solvent resistance [20] .Polymers are important due to the ability to modify , and its inherent physical properties.With the addition of fillers and retaining their characteristics,polymers can be stronger and stiffer [21-23] . PMMA is a polymeric material that has many desirable properties like high transmittance, light weight, uncoloured, chemical resistance, and resistance corrosion to weathering. PMMA can be improved by doping [24].

The matrix material can be strengthened during the manufacture stage of the composite [25]. Polymer blends are most obtained by mixing two or more components from heterogeneous systems.PMMA is an economical, purpose material and versatile general . It is cast material in sheet and rodtube forms , available in extruded . Acrylics are used Various of types in a wide fields of variety applications, including: Properties of PMMA such as a linear thermoplastic polymer .PMMA is a linear thermoplastic polymer, PMMA hasbackbone carbon chain and its long polymer chains are smoother and thinner and can slider each other more easily, so the material becomes more softer .

1.1. The aim of the research study

There is a problem with dentists, which is the fragility of PMMA material when used in the patient's dental prints.In this paper, the problem was treated by adding nanoparticels and renforcement PMMA .

2. Materials and preparation

2.1. Matrix of the material:

a. (PMMA) cold curing , type (Castavaria) made by (Vertex – Dental Company), ertex™ Castavaria is a multifunctional self-polymerizing acrylic which is perfectly useable as a pouring, relining, rebasing and as a repair acrylic.

b. Powder material Nano particle ($ZrO_2Y_2O_3$) , made by ChendguHaoxuan Technology Co,. Radius (40-115) nm, shape spherical, Assay 99.999% , China

2.2. Preparation of casting mold samples:

a) Samples are prepared according to the rates in ($ZrO_2Y_2O_3$) as shown in table (1):

Table (1) The percentage of reinforcement (ZrO_2Y2O_3) nanoparticels in the base material PMMA

PMMA %	$ZrO_2Y_2O_3$%
100	0
99.5	0.5
99.0	1
98.5	1.5
98	2
97.5	2.5

b) After 24 hours the sample is taken from the mold and is inserted into the electric furnace temperature (60^{o}C) so as to make the treatment process and keep the sample in the oven

for (55) min.This is the necessary stage to obtain the best interlock and to remove the stresses generated by the manufacturing process .

3. Mechanical Properties Testing

3.1. Tensile test

Samples were cut according to (American society for testing materials) (ASTM D) specimen. The machine used for the testing of tensile properties is micro computer controlled electronic universal testing machine (model WDW 200 E) made in China The test was conducted at velocity of (1 mm/min) at ambient temperature, tensile stress was applied till the failure of the sample and stress-strain curve was obtained.

3.2. Flexural strength

Bending behaviour of the prepared sample is tested using a three point test instrument, (model WDW 200 E) made in China, at room temperature and after fixing the ends of the sample on the supports of the instrument, the weights are increased gradually at the middle of the sample with velocity (5mm/min) until the failure of the specimen occurred.

3.3. Impact test

It is considered one of the most important mechanical tests that give the absorption of energy that is required for fracture of the sample which is given directly from the device. The impact test instrument model is XJU-22 . The sample is placed vertically; the testing method of this instrument includes lifting of pendulum to its maximum height and fixing it firmly where its potential energy would be changed to kinetic energy.

3.4. Hardness test

Shore D has been used to measure the hardness of the samples, which must have smooth, plain surface with thickness at least more than (3mm) and must not be exposed to mechanical vibrations so that the prepared sample has (8×8×5) mm^3. These dimensions were taken according to ASTM-D570. Shore instrument is similar to compass containing needle placed in a position perpendicular to the sample and it takes waiting (0.5 min) to read the value and to have some accuracy an average of ten readings have to be taken in different locations and at different points for each sample

3.5. Compression test

The sample for this test is prepared according to ASTM with dimensions (2×1×1) mm^3, depending on thickness of the sample. The test is conducted at velocity of (0.5mm/min) at ambient temperature. The machine for the testing of compression is made in China and it is model (WDW200E). The load is applied gradually to the longitudinally fixed sample, the increasing of the load continued until the failure of the specimen occurred.

4. Result and discussion

4.1. AFM Test

The practical size distribution of this powder is carried out by atomic force microscopic (AFM) using scanning probe microscopy (SPM) the result of practical size distribution of $ZrO_2Y_2O_3$ as shown in table (2) and figure (1) where average value of diameter between of (20-115 nm)

Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)	Diameter (nm)<	Volume (%)	Cumulation (%)
20.00	0.34	0.34	60.00	4.83	10.34	90.00	10.00	60.34
35.00	0.34	0.69	65.00	4.83	15.17	95.00	7.59	67.93
40.00	0.69	1.38	70.00	7.93	23.10	100.00	6.55	74.48
45.00	0.69	2.07	75.00	7.24	30.34	105.00	10.69	85.17
50.00	1.72	3.79	80.00	10.34	40.69	110.00	7.59	92.76
55.00	1.72	5.52	85.00	9.66	50.34	115.00	7.24	100.00

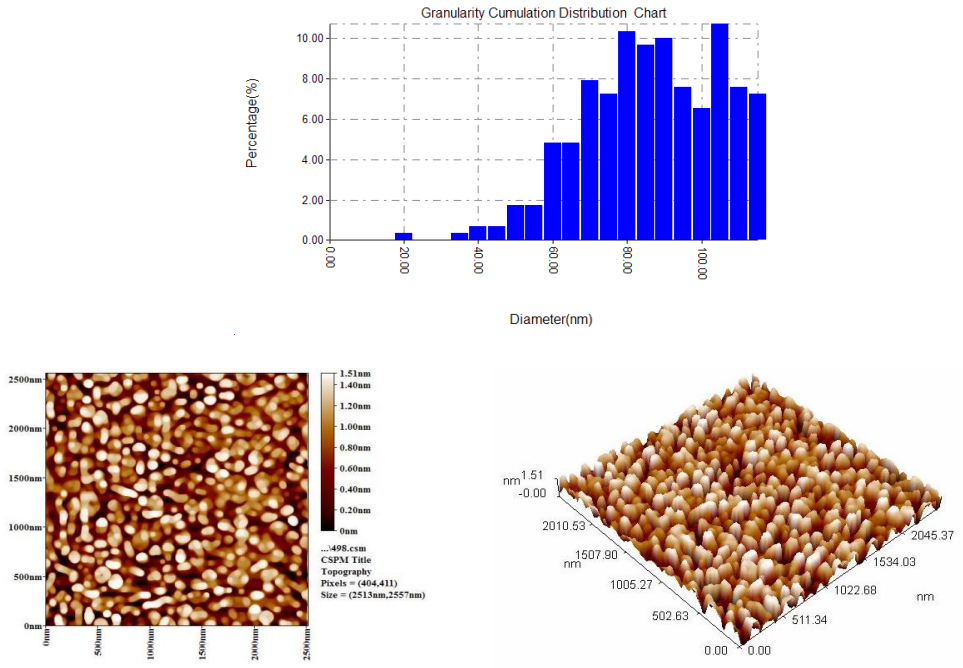

Fig.1. (Image AFM nanoparticels ($ZrO_2Y_2O_3$)

4.2. Tensile test result:

Fig.(2) shows the stress-strain curves of (PMMA:$ZrO_2Y_2O_3$) as a proportion to $ZrO_2Y_2O_3$. It is found from the figure that the best stress value is at ratio (1%) from nanoparticles $ZrO_2Y_2O_3$.

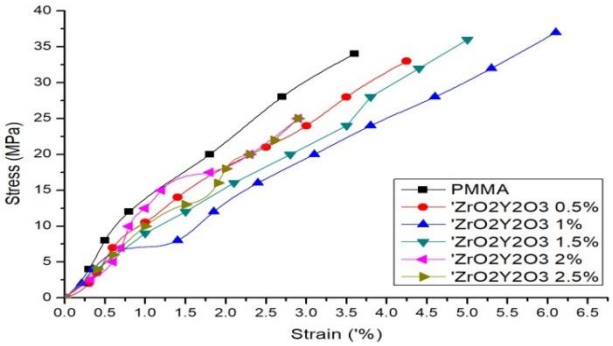

Fig. 2. (Stress-strain curves of the polymer blend (PMMA:$ZrO_2Y_2O_3$) as proportion of $ZrO_2Y_2O_3$)

It is observed that curves (stress - strain) consist of the deformation regien .This region has the flexibility coefficient, which represents by straight line. Polymer within the boundaries of this

region is distorted due to tensile and elongation of the chains of polymeric without breaking the bonds. Then this curve deviates from linear behavior is a result of the crack inside the polymeric material. These cracks grow and accumulate with increasing stress composed cracks larger and continues to grow with a stress until it gets in the fracture sample. In other cases, the fracture starts at the outer surfaces of the positions deformation or defects such as for scratches bond or internal cracks and working zones of concentration of stresses that lead to the high value of the stress to exceed the limits of the force of internal bonds , thus break happens [26].The increase in the proportion of metal additives nanoparticles increase the flexibility of the material and thus increases the tensile ratio and this is due to the distribution homogenized with metal additives nanoparticles lead to greater coherence between the components of the mixture polymer, in addition to increasing the complexity of polymeric chains in the mixture, and thus leads to increased tensile properties (resistance tensile strength and modulus of elasticity) of the polymer material [27] .

Fig. (3) shows the flexural strength curves of (PMMA:$ZrO_2Y_2O_3$) as a proportion of $ZrO_2Y_2O_3$. It is found from the figure that the best flexural value with 1% from $ZrO_2Y_2O_3$.

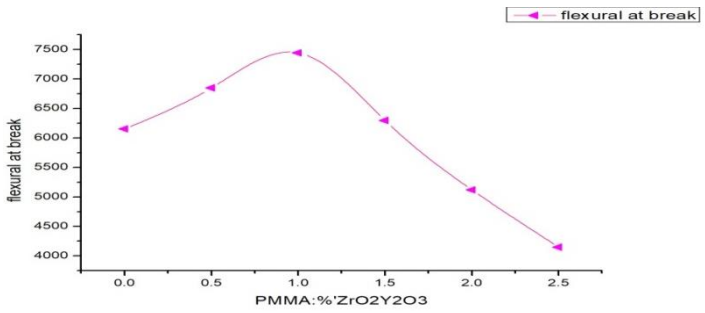

Fig.3.(shows the flexural strength values for the polymer blend (PMMA: $ZrO_2Y_2O_3$) as a Relative to$ZrO_2Y_2O_3$)

It is observed that the best value of flexural stress of the sample(1%) reinforced nanoparticles $ZrO_2Y_2O_3$.in best ratio (1%). The reason to attribute to the strong correlation between partials of $ZrO_2Y_2O_3$ and material basis , as the strong bonds will not allow the formation of internal defects (cracks) is fast, small particles into the Interfaces space within the reinforced metal network , do not work any defects inside the material. This increases the ability of the middle and moistening reinforced materials in an integrated areas, and then, increasing the contact interface area between the reinforcement material and matrix material, therefore increasing the strength of the connections between the components of material overlapped. The reinforcement materials have higher than the base material flexibility [28]. The bending resistance decreases slightly with adding nano-material to the material foundation of values, The reason to the bending resistance depends on the defects and cracks within the substance [29] .The bending resistance values decreases with increasing fracture when nanoparticles added.This is due to the nature of the reinforced material of nanoparticles added as the nanoparticles tend to form agglomerate of soft or hard each with its own function.The stress of loding may not work as an adjective barrier to developing cracks through the material overlapped and do not work on disability crack growth and this will change the shape of crack and direction leading to its transformation into a minor cracks group causing the decrease in bending resistance values [30].Furthermore, the particles reinforced may create some defectsin the material basis, especially in areas containing agglomerate of nanoparticles because it isnot distributed uniformly, and this will serve as centres for the concentration of stresses causing a decrease in resistance to bending.

Fig.4 showscurves to young modules of (PMMA:$ZrO_2Y_2O_3$) as proportion a$ZrO_2Y_2O_3$, observed the best value Young modules at ratio (1%) from$ZrO_2Y_2O_3$ Nano.

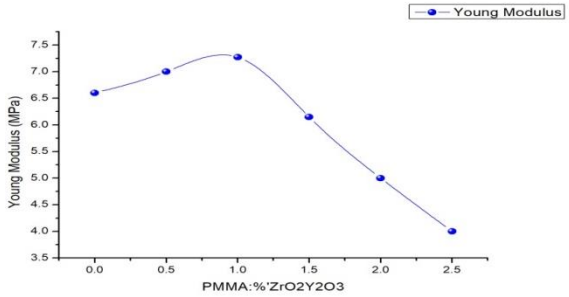

Fig.4.(Young modulus of the polymer blend (PMMA: $ZrO_2Y_2O_3$ as a proportion of $ZrO_2Y_2O_3$)

Bending resistance significantly affected as strongly linked to the base material and reinforcement material which facilitates the penetration of the base material process in the reinforced materialsand the moist.This leads to increased interoperability bonding area between the material matrix and materials reinforced which increases the bonding strength after hardening and ultimately increase the flexibility bending transactions [31].

Fig.5 showsthe curve of the elongation (PMMA: $ZrO_2Y_2O_3$) as a proportion a$ZrO_2Y_2O_3$,The best value ofelongationis observed at 1% from nanoparticles $ZrO_2Y_2O_3$, the reason for this is due to the nature of the rigid nanoparticles, particles working to reduce the distance between the matrix molecules , which lead to reduce fragility .

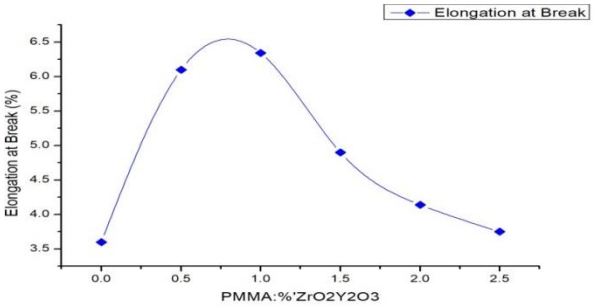

Fig.5. (Elongation at break of polymer blend (PMMA: $ZrO_2Y_2O_3$) as a proportion of $ZrO_2Y_2O_3$)

It is noticed that the elongation values are decreased with increasing content nanoparticles in a material basis and this could be due to the nature of the distribution of reinforced nanoparticles inside the matrix material and weak wetting with the matrix metal. This reduces the contact interface area between the material matrix and materials reinforced. Also The conglomerate nanoparticles inside the material matrix will weaken the strength of the connections between the components of material composite and the conglomerate (collection). The adhesion of these powders nanoparticles together, will play an important role in the concentration of stress. When tensile stress is applied on the sample, the intensity will increase the pressure concentration dramatically near the gatherings nanoparticles (collection) and this leads to decode correlation between nanoparticles and material matrix and will contribute to the rapid spread of cracks inside the material, and thus leads to get an early break of samples[32,33].

4.3. Impact test

Fig. 6 shows the curve (PMMA: $ZrO_2Y_2O_3$,) as a proportion of $ZrO_2Y_2O_3$, observed that the best value Impact with the ration (1%)$ZrO_2Y_2O_3$. The value of Impact decreases , because metals create a lot of defects , which serve as centers of concentration of stresses and break the power and thus reduces the Impact values . This change in the form of slit and direction lead to reduce the surface area of the break and the energy expended and these factors led to the decrease

of the resistance Impact of the samples [34] . It is noticed that the elongation values are decreased with increasing content the nanoparticles in a material basis. This could be due to the nature of the distribution of reinforced nanoparticles inside the matrix material and because of the weak wetting of the matrix metal , which reduces the contact interface area between the material matrix and materials reinforced .

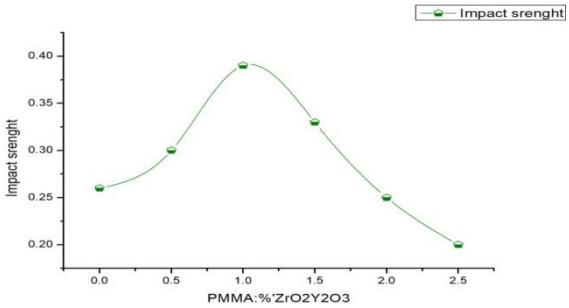

Fig.6. (Effect of polymer blend (PMA: $ZrO_2Y_2O_3$) as a function of $ZrO_2Y_2O_3$)

Fig.7 shows the curve of the (PMMA: $ZrO_2Y_2O_3$) as a proportion of $ZrO_2Y_2O_3$the value of fracture toughness is best with (1%) from nanoparticles$ZrO_2Y_2O_3$ .And that the reason for the increase in strength as a result of wet nanoparticles inside material matrix , but the decrease in strength is due to the increase in the proportion of nanoparticles in matrix and least wetting and the formation of coalitions of powder reinforcement material that claim to reduce the impact factor.

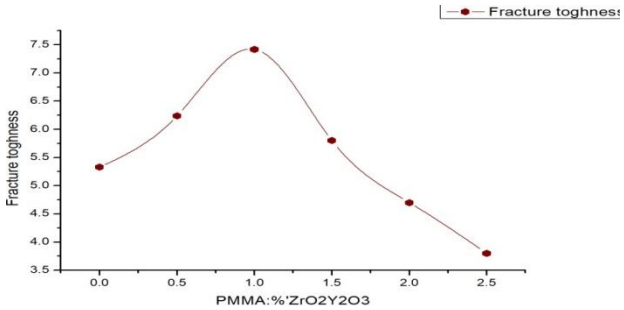

Fig.7. (Effect of polymer blend (PMA: $ZrO_2Y_2O_3$) as a function of $ZrO_2Y_2O_3$)

4.4. Hardness test

Fig.8 shows the curve of the first group (PMMA: $ZrO_2Y_2O_3$) as a proportion of $ZrO_2Y_2O_3$ and the best value of hardnessis 1% from $ZrO_2Y_2O_3$Nnoparticels. When we add the hight ration from Nanoparticels the value of hardness decreases , because of what is added to the material foundation has worked to reduce distances and gaps between molecular. This increases the hardness of the mater causing ease of penetration material composite which leads to a reduction of gaps inside the material [17,18]

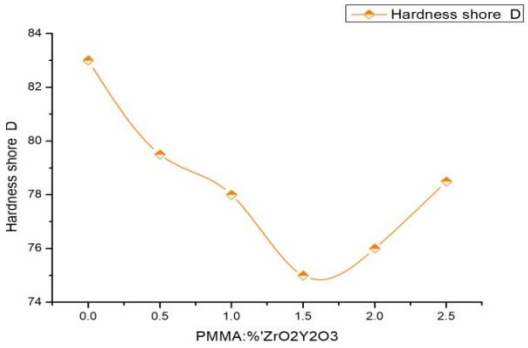

Fig.8. (Hardness of polymer blend (PMMA: $ZrO_2Y_2O_3$) as a function of $ZrO_2Y_2O_3$)

4.5. Compression test

Fig. 9 shows the compression curves of the (PMMA: $ZrO_2Y_2O_3$ as a function of $ZrO_2Y_2O_3$ and the best value of compressionis (1%) of the nanoparticles $ZrO_2Y_2O_3$.

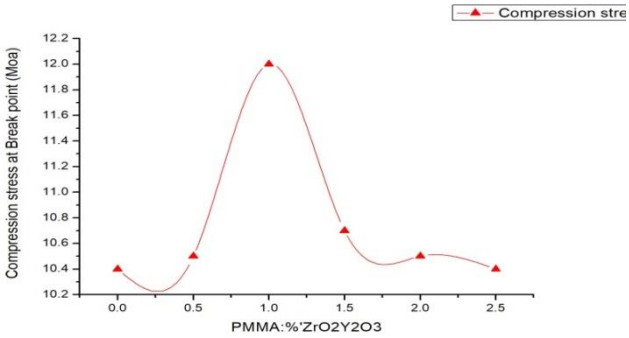

Fig. 9.(The compressive strength of polymer blend (PMMA: $ZrO_2Y_2O_3$ as a function of $ZrO_2Y_2O_3$)

Because of its reinforced material to resist high compression compared to the material basis on polymeric addition, and as previously stated easier penetration of $ZrO_2Y_2O_3$ Nano into the space area interfaces between the polymeric chains lead to a reduction in the vacancy inside the base material and thus increase the compressive strength [19].

4.6. Bending Test:

Fig. 10 shows the compression curves of the (PMMA: $ZrO_2Y_2O_3$ as a function of $ZrO_2Y_2O_3$ and the best value of the compressionis (1%) of the nanoparticles $ZrO_2Y_2O_3$ **.**

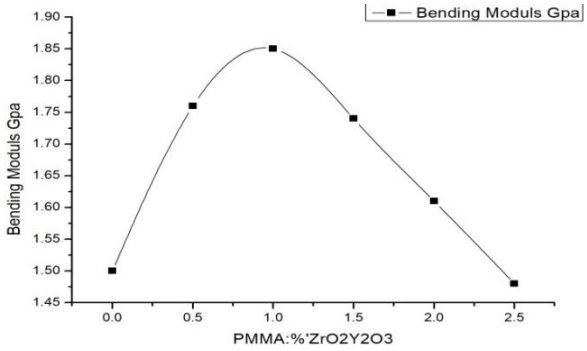

Fig. 10. (Bending of polymer blend (PMMA: $ZrO_2Y_2O_3$ as a proportion of $ZrO_2Y_2O_3$)

5. Conclusion

Adding Nanoparticels ($ZrO_2Y_2O_3$) to the matrix material PMMA lead to get new matireal that has mechanic properties to rduec the fragility of the material matrix .

The best mechanical tests are at the percentage of (1%) of the ($ZrO_2Y_2O_3$)Nanoparticels when added to the base material PMMA .

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