Study of Some Mechanical and Physical Properties of Cold Curing Acrylic Resin Reinforced with Particle Yttrium Oxide

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Abstract

Over the past thirty years, composite materials are being used extensively in many applications; this is due to proven fact that composite materials such as high stiffness, high strength, low thermal conductivity. In this study we used particle Yttrium oxide (5%, 10%, 15% and 20%) as reinforcement to cold curing acrylic resin. Many mechanical and physical tests were used to determine the properties of the prepared composite material which involved tensile strength, toughness, hardness, thermal conductivity, density and water absorption. The results had shown that the tensile strength and toughness decreased with increasing weight fraction of Y_2O_3. The hardness has been increased with increasing weight fraction of yttrium oxide especially at (5%, 10%, 15%). thermal conductivity increased with increasing volume fraction of yttrium oxide, maximum density was obtained at (15% wt.) of Y_2O_3 reinforced composites. Water absorption decreased with increasing weight fraction of Y_2O_3.

Keywords: cold curing acrylic resin, particle Yttrium oxide, reinforced, Mechanical properties, physical properties.

1. Introduction:

Polymethylmethacrylate PMMA has proved to be the most satisfactory denture base material currently available. Almost all dentures are being fabricated with this type of polymer [1]. PMMA's favorable characteristics are used as a denture base material such as: Ease of processing, Pigmentable, High polish attainable, adequate strength, easy to repair after fracture, low water sorption, low solubility, relatively low toxicity, odourless and tasteless. PMMA's unfavorable characteristics such as: Large polymerization shrinkage, high thermal expansion co-efficient, radiolucent, allergy possible.

Chemically cured, Cold Curing Acrylic Resin, PMMA is auto polymerized, this means that the polymerization reaction starts as soon as the powder and liquid components are mixed together, these are therefore kept separately until required. The benzoyl peroxide initiator present in the pre-polymerized poly (methylmethacrylate) spheres may also be activated by chemicals, in this case, no heat is required for the polymerization reaction to occur. Dimethyl-ptoluidine, a tertiary amine, is used to activate the polymerization reaction in chemically cured PMMA. After polymerization has commenced, the reaction is the same as for heat cured materials [2].

The degree of polymerization of cold cured acrylic resin is not as complete as that achieved using heat cured system which leads to a higher degree of unreacted residual monomer, which act as a plasticizer which results in high transverse deflection values lowering the transverse strength of the resin. High liquid-powder ratio may also resulted in increasing the residual monomer concentration [3].Chemically cured materials rarely exhibit the same degree of polymerization as heat cured materials, for this reason, their strength and hardness values are lower. It is possible to exhibit a degree of control over the rate of material hardening by altering the size of polymer particles and the volume of dimethyl- p – toluidine added. Furthermore, there is no polymerization shrinkage so these materials may be considered more dimensionally accurate than heat cured types[4].

Reinforcement has been attempted through the incorporation of solid metal forms and various types of fibers in fracture– prone areas.

The addition of fibers to acrylic resin has the potential to improve the mechanical properties of the material. Effective fiber reinforcement is dependent on many variables including the material used, the percentage of fibers in the matrix and their modulus and distribution, fiber length, fiber orientation and fiber form. Over the years various types of fibers such as carbon, aramid, polyethylene, and glass have been added to acrylic resin in an attempt to improve its mechanical properties [5]. The aims of this study were to evaluate the effect of reinforcement on the mechanical properties of acrylic resin denture base material.

Among the different eutectic ceramic oxides, the Al_2O_3 – $ZrO_2(Y_2O_3)$ system is one of the most interesting materials from the point of view of its mechanical properties as well as its strength retention at high temperature. The flexure strength at ambient temperature of the first Al_2O_3 –$ZrO_2(Y_2O_3)$ eutectics manufactured in the 1970s and 1980s was modest (B600 MPa), but this strength was retained up to 1850 K, at which flexure strength values of up to 524 MPa were measured. Significant improvements in the processing techniques in the last decade had demonstrated that ambient temperature strengths in the range 1.0–1.5 GPa can be obtained by carefully controlling the microstructure [6]. This present work, studies the effect of particle yttrium oxide as reinforcement of cold curing acrylic resin on some mechanical and physical properties.

2. Experimental:

2.1. Material and Methods:

The raw materials needed for preparing the composites are Yttrium Oxide particle (Y_2O_3) powder of (200-250 nm) particle size were used. Cold-Curing denture base resin (Self-curing denture base resin) from Duracryl® Plus: Duracryl Plus the denture base resin is used to repair the removable dentures and manufacturing of immediate dentures. It consists of two bottles of powder and liquid :

Powder: PMMA prepolymer or copolymer (fine particle size), Di-benzoyl peroxide (DBP)(initiator) (1-2%), Pigment (1%).

Liquid: Methylmethacrylate monomer MMA, Glycol dimethacrylate as cross-linking agents (1-2%), Hydroquinone (inhibitor) (<1%), Dimethyl-p-toluidine (activator).

2.2. Cast Mold

The cast mold used for casting the composite specimens, with dimension (30 cm x 21cm), consists of two tensile mold specimens and four molds of hot disk specimens as shown in figure (1). This mold is made of iron and consists of two plates. These plates have been made so they must be free from defects. Before casting the mold, it was lubricated by Vaseline to facilitate the extraction of specimens.

Figure (1): Tensile and hot disk mold.

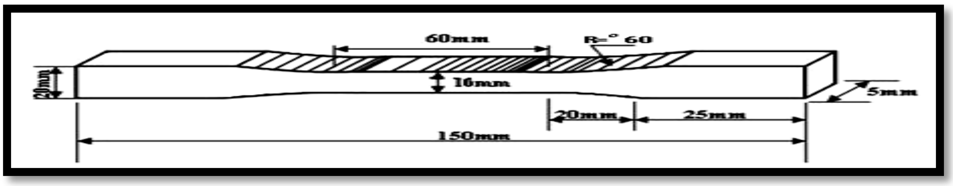
2.3. Preparation of Composites

The resin (super acrylic plus) and the crosslinked denture were used in addition to particle Y_2O_3 as reinforcing material the mixture was put in the molds standard samples which were prepared by adding the (cross- linked) to the (super acrylic plus) in ratio of (3 : 1) . Then the standard sample was weighed. , the sample of the composite materials was prepared by adding the reinforcing material (Y_2O_3: 5%, 10%, 15%, 20%) to the matrix. The samples were left for twenty four hours to dry.

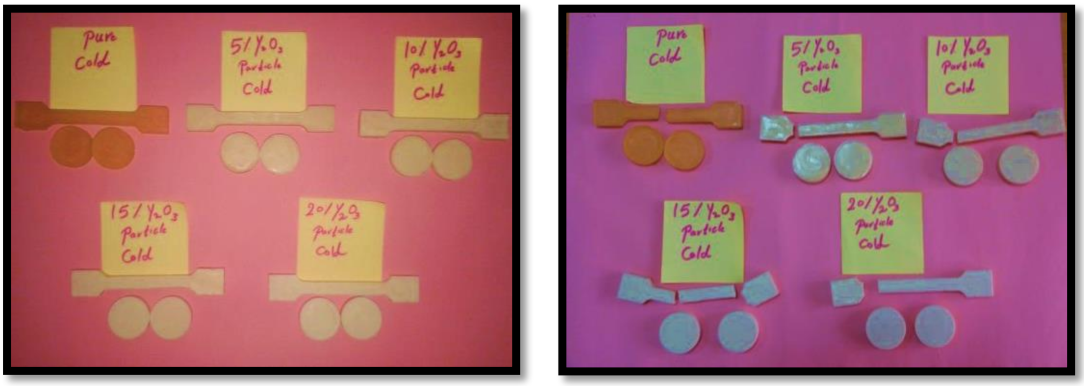
2.4. Mechanical and Physical Tests

2.4.1. Tensile test

The tension test generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen and the straight sided piecemeal with and tabs. The standard test method as per ASTM 638-01. The length of the test specimen used is (150 mm). The tensile test is performed in universal testing machine (UTM) machine with a loading capacity 50k. tests were performed with a cross head speed of (5mm/min) for each test composite of all samples were tested and average value was taken for analysis [7]. Toughness was calculated from the area under the curve of the scheme (stress-strain) for all samples which used in this research by using Mat. Lab. Math. Works program (Trapezoidal method).Figure (2) shows a standard specimen for tensile test and tensile specimens before test and after test.



(A)



(B) **(C)**

Figure (2): tensile test specimen: (A) Schematic specimen, (B) Some tensile specimens before test and (C) after test.

2.4.2. Hardness test :

Hardness is the characteristic of a solid material expressing its resistance to scratching, cutting, wear, indentation, penetration and machinability. Hardness covers: Elasticity, Plasticity, Strength and strain, Brittleness/ ductility and toughness. Hardness increases with decreasing particle size. This test was performed using Shore hardness (D) (Elcometer), according to (ASTM D2240), with the test specimen prepared shown in figure (3) at the room temperature [8].The mean hardness value of the five measurements H is defined as follows:

$$\square H=\frac{H1+H2+H3+H4+H5}{5}$$

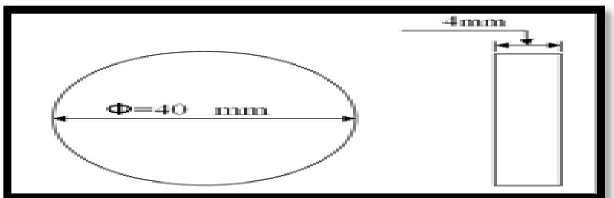


Figure (3): Hardness test Schematic specimen

2.4.3. Density Test

The density test was performed according to (ASTM D792) by using displacement method based on Archimedes theory. In this test any convenient size of specimens can be used, but the volume should not be less than (1cm3) and surfaces of the specimens as well as edges must be smooth and free from (oil, grease and other foreign matter). The specimens were tested must be weighed in air and weighed when immersed in distilled water, and density can be obtain by applying the following equation:

$$\text{Specific gravity} = Wd / Wd - Wi$$

Where: Wd : Mass of dry sample (gm), Wi : Mass of sample after immersing and suspended in water (gm). Specific gravity can be converted to density (gm/cm3) by multiplying the specific gravity by which represented the density of distilled water (gm/cm3) that equal to (0.9975) [9]

2.4.4. Water Absorption Test

The water absorption test was performed according to (ASTM D570). In this test, the specimen was immersed in distilled water under specific temperature and time. By entirely immersion of the specimens in container of distilled water at room temperature (23 ±2) and left on an edge for (24hr), after that the specimens were removed from distilled water. Then, all surfaces water wiped off with dry cloth and weighed by digital balance, the water absorption was obtained by applying the following equation [10] :

$$\text{Water Absorption } \% = (Ws - Wd / Wd) \times 100$$

Where: Wd : Mass of dry specimen before Immersion, Ws: Mass of specimen after immersion in distilled water for (24 hr) at room temperature.

2.4.5. Thermal conductivity test:

Thermal conductivity (TC) provides the thermal properties of developed composites. The test was performed on Hot Disk Thermal constants analyzer device (type: TPS 500, made in Sweden). and The samples used in this test have diameter (40 mm) and (10 mm) in thickness.

3. Results and Discussion:

Results discussions include, the mechanical properties of the prepared hot curing acrylic resin before and after reinforced with yttrium oxide at different weight frication (0%, 5%, 10%, 15%, and 20%). The effect of reinforced by adding particle yttrium oxide on cold curing acrylic resin, mechanical properties such as tensile strength, toughness and hardness test studied in addition to physical properties such as thermal conductivity, density and water absorption.

Tensile strength:

Figure (4) shows the tensile strength for cold curing acrylic resin with different weight factions (0, 5, 10, 15 and 20%). Based on figure (4), it is clear that the particle Y_2O_3 reinforced cold curing acrylic resin decrease the tensile strength. . The reasons behind such behavior because of the yttrium oxide particle act as a tensile concentrator rather than acting as reinforcement [11, 12].

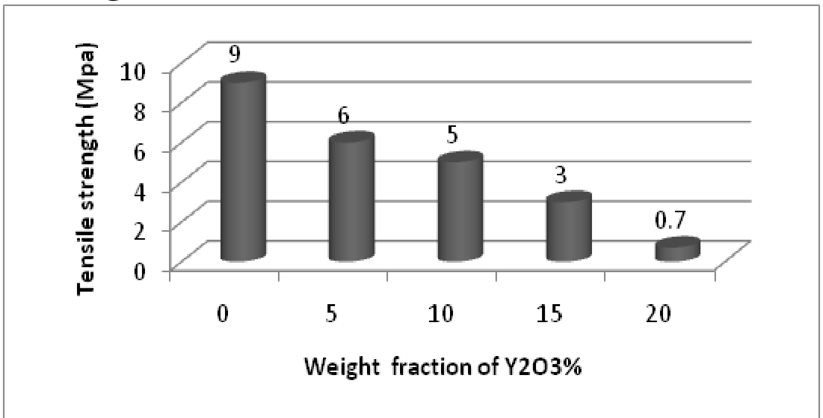


Figure (4): The relationship between the tensile strength and the weight fraction of the particle yttrium oxide which were added to the cold curing acrylic resin.

Toughness

Figure (5) shows the relationship between the toughness and the weight fraction of the filler particles yttrium oxide, which were added to the cold curing acrylic resin. The figure illustrates that the toughness decreases with increasing weight fraction of yttrium oxide for cold curing acrylic resin. This are may be attributed to the particle homogenous distribution of yttrium oxide throughout the composite for higher yttrium oxide content. This leads to formation of regions that require low energy for crack propagation [11,13].

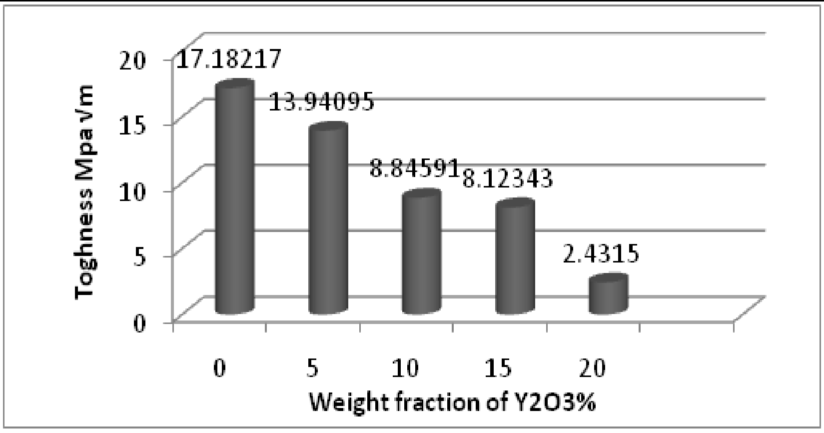


Figure (5): the relationship between the toughness and the weight fraction of the particle yttrium oxide

Hardness Test:

This test was performed by (shore D) measurement for hardness test and by calculating the average reading. Figure (6) shows the relationship between the hardness and the weight fraction of the particles yttrium oxide which were added to the cold curing acrylic resin, It can be noticed that the values of hardness increased slightly with increasing of the weight fraction of particles yttrium oxide. This is related to the high hardness and brittleness that have these particles as compared with cold curing acrylic resin. Furthermore, related to the wettability and the bonding strength between the matrix and these particles, which lead to make the harder surface by impeding the matrix motion along the stress direction. That's where we get the maximum hardness when we use particles yttrium oxide of 15% as a reinforced. And also note a slight increase in material hardness when using ratios of 5% and 10%. the results had shown that the hardness test are better when used particles yttrium oxide as reinforced for cold acrylic resin

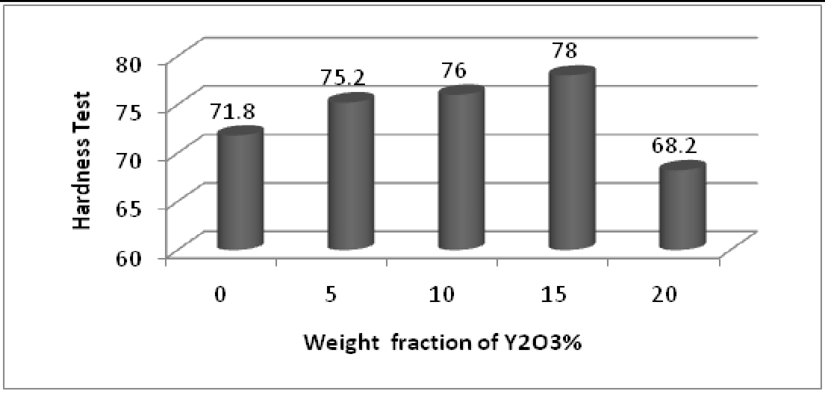


Figure (6): the relationship between the hardness test and the weight fraction of the yttrium oxide which were added to the cold curing acrylic resin.

Thermal conductivity:

It is observed from figure (7) that the effective thermal conductivity of composites was higher than that of virgin polymer. This behavior can be explained on the basis of compact structure of composites. When the particles are introduced into the matrix, they acquire the position of voids and reduce the free volume (voids filled with air) resulting into compact structure of composites, which improves the thermal conduction or thermal conductivity of composites over the pure cold curing resin [14].

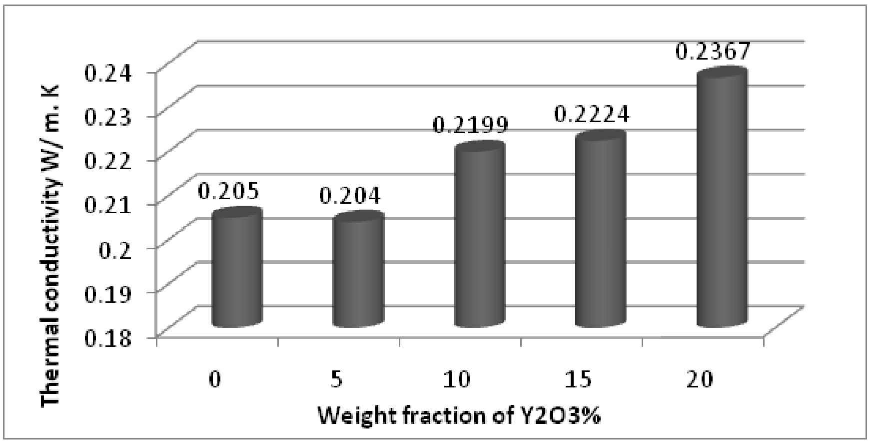


Figure (7):the relationship between the thermal conductivity and the weight fraction of the yttrium oxide which were added to the cold curing acrylic resin

Density Test:

Figure (8) show the relationship between the weight fraction of yttrium oxide particle and density of cold curing resin composites, It can be noticed that the values of density increased with increasing of the volume fraction of particle yttrium oxide in (10%.15%.20%), This is due to the fact that these particles have high density value compared with the cold curing resin. In addition, these particles are made to diminish or fill the voids and spaces which were inside the curing resin, at finally result gives denser composite specimens with same volume.

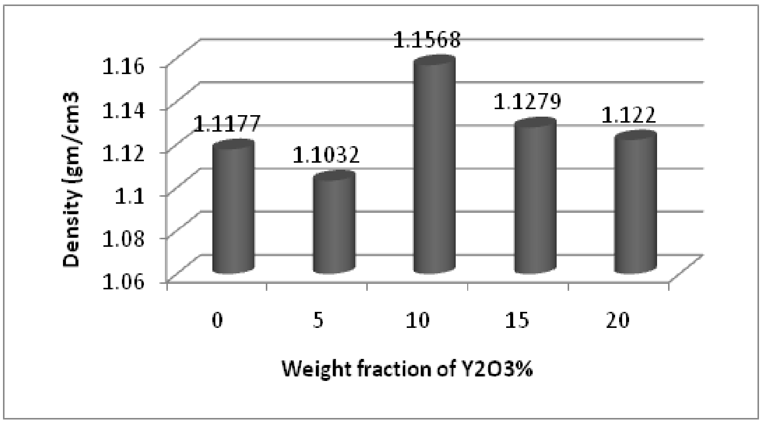


Figure (8): the relationship between the density and the weight fraction of the yttrium oxide which were added to the cold curing acrylic resin

Water Absorption

Figure (9) show the relationship between the weight fraction of yttrium oxide particle and water absorption of cold curing resin composites. It can be noticed that the values of water absorption percentage decreased with increasing of the weight fraction of particle yttrium oxide due to when the addition of fine particles such as yttrium oxide, all the spaces and voids which were inside the cold curing acid will be diminished or filled by these particles, therefore, result the water absorption percentage will be decreased for prepared composite specimens.

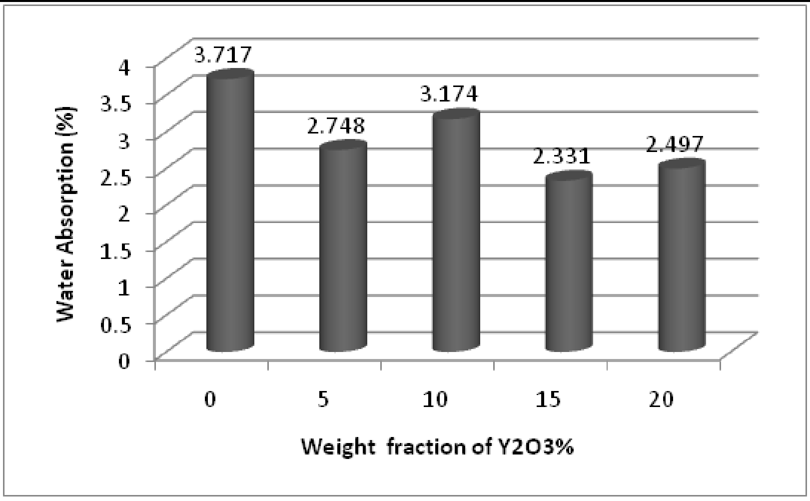


Figure (9): the relationship between the water absorption and the weight fraction of the yttrium oxide which were added to the cold curing acrylic resin

Conclusions

The addition of fillers yttrium oxide to cold curing acrylic resin leads to an improvement of some mechanical properties. For the prepared composite material with yttrium oxide, the results had shown that the mechanical properties such as hardness test have been increased with increasing weight fraction of yttrium oxide at use value at (5%, 10%, 15%). Furthermore, the increasing in weight fraction revealed a decreasing in the evaluated properties such the tensile test and toughness test decreased with increasing weight of particle yttrium oxide, thermal conductivity increased with increasing volume fraction of yttrium oxide, maximum density was obtained at (10% wt.) of Y_2O_3 reinforced composites.

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الخلاصة :

على مدى السنوات الثلاثين الماضية استخدام المواد المركبة على نطاق واسع في العديد من التطبيقات. ويرجع ذلك إلى هذا أن المواد المركبة تتحسن فيها الصفات مثل زيادة الصلابة ، والمتانه ، وانخفاض التوصيل الحراري. في هذه الدراسة استخدمنا جسيمات أكسيد اليتيريوم بنسبه (5٪، 10٪، 15٪ و 20٪) كتعزيز لراتنج الاكريليك البارد. وقد استخدمت العديد من الاختبارات الميكانيكية والفيزيائية لتحديد خصائص المواد المركبة المحضره مثل اختبار قوة الشد، اختبار الصلابة، اختبار التوصيل الحراري و اختبار الكثافة وامتصاص الماء. إن النتائج أظهرت أن قوة الشد والمتانة انخفضت مع زيادة الوزن من جسيمات Y2O3 ازدادت صلابة مع زيادة الوزن من أكسيد الإيتريوم خاصه عند نسبه (5٪، 10٪، 15٪). التوصيلية الحرارية تزداد مع زيادة نسبه حجم أكسيد الإيتريوم، تم الحصول على أقصى قدر من الكثافة عند تعزيز المتراكبة بوزن (15٪) من Y2O3 .لقد انخفض امتصاص الماء مع زيادة النسبة الوزنية منY2O3