MERIT RESEARCH JOURNALS
www.meritresearchjournals.org
Merit Research Journal of Medicine and Medical Sciences (ISSN: 2354-323X) Vol. 6(8) pp. 298-302, August, 2018
Available online http://www.meritresearchjournals.org/mms/index.htm

Original Research Article

The effect of Li_2SiO_3 Nano-fillers addition on some mechanical properties of heat cured polymethyl methacrylate denture base material

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Abstract

Nano composite materials based on polymers are widely used in restoration materials like dental. Poly methyl methacrylate (PMMA) is one of the most used polymers as dental material. PMMA has disadvantages such as low flexural and impact strength properties. In this study investigation has been done to found the effect of the addition of Nano-lithium silicate on transverse strength, impact strength and hardness of heat cured PMMA. A total of 72 specimens were prepared. 48 specimens of each group were fabricated with dimensions of (65×10×2.5) mm to conduct the transverse strength and hardness tests, while the remaining 24 specimens of each group were fabricated with dimensions of (80×10×4) mm to perform the impact strength test. The results of this study showed that the higher increasing value in the transverse, and impact strength found when added (1.0 % Li_2SiO_3), while 1.5%Li_2SiO_3give the highest mean value in hardness test.

Keywords: Heat cured PMMA, Nano- lithium silicate

INTRODUCTION

The hot-cured PMMA is one of very important material in dentistry which is referred to as acrylic resin has been introduced for using in dentistry since the early1930 (Nihad, 2014). Acrylic resins are the most used material to produce removable prosthetic devices due to low cost, easy handling and satisfactory properties (Lisiane, 2012; Rahul et al., 2010). Acrylic resins have relatively low values of specific gravity, poor impact strength, and relatively poor resistance to fatigue fracture (John, 2008).

The physical, mechanical and aesthetic properties and the clinical behavior of composites depend on their structure (Adela et al., 2006). Research conducted strength, elasticity modulus, wear resistance, polymerization shrinkage and generally, the physical and mechanical properties of the composite are improved in direct relation to the amount of micro or nano fillers added (Karimzadeh et al., 2014; Nidal et al., 2014). There are several properties of resin composite that makes it a more favorable restorative material than many others (Keith et al., 2010).

Dental ceramics are usually referred to as nonmetallic, inorganic structures primarily containing compounds of oxygen with one or more metallic or semi-metallic elements like aluminum, calcium, lithium, magnesium, phosphorus, potassium, silicon, sodium, zirconium and titanium (Jithendra et al., 2015). Due to its low thermal expansion, low density and high strength, lithium-silicate ceramics are the object of a still growing number of research works.

It finds use for electronic equipment and in lithium batteries. It was published that lithium ceramic exhibits a very high absorption ability for carbon dioxide CO2 at higher temperatures. Lithium silicate ceramics is also widely used in dental applications (Tomáš et al., 2017).

Nanoparticle-reinforced polymer composites (NRPs) are receiving special attention, especially for bonding applications in automotive, marine, aerospace, oil, and gas industries. NRPs are known to enhance the mechanical, electrical, thermal, and permeability properties and diffusion barrier attributes of their host polymers. Moreover, in some cases, they could also provide self-healing ability. The enactment of mechanical properties gained by inclusion of nanoparticles includes improved strength and stiffness to weight and cost ratios, improved fatigue and corrosion resistance, more controllable damage mechanism, and augmentation of the energy-absorption capacity of their host polymer (Soltannia et al., 2016; Karimzadeh et al., 2014).

MATERIALS AND METHODS

The materials used for denture base are heat cured acrylic resin poly (methylmethacrylate), monomer methylmethacrylate (PMMA, MMA, SpofaDental a. s., Czech). The mold materials are made from (di stone, pink, Bulgaria). While, nano-lithium silicate as liquid **(**XINSEN YVANCO., ltd, Ph= 11.47, density= 1.18%, SiO_2= 19.6%, Li_2O= 2.02%) was used to reinforce the denture base materials.

The nano lithium silicate material added during mixing of powder and liquid of PMMA. The percentages and the amounts of polymer and monomer where shown in Table 1.

Table 1. Percentages and amounts of polymer, monomer and lithium silicate Nano filler used in the study

Nano Li_2SiO_3 Percentage	Amount of Nano Li_2SiO_3	Amount of PMMA	Amount of monomer
0	0	22gm	10ml
0.5%	0.11gm	21.89	10ml
1%	0.22gm	21.78gm	10ml
1.5%	0.33gm	21.67gm	10ml

Specimens grouping

Seventy two specimens were prepared to be used in the present study. The specimens were divided into (3) groups according to the tests used, for each test (4) subgroups (three for nano- lithium silicate addition and the other control) where each sub group contain six specimens to be tested.

General preparation of test specimens

Preparation of the acrylic specimens (Test specimens):
1. Include Plastic model preparation.
2. Proportioning and mixing of the acrylic.
3. Addition of filler.
4. Packing.
5. Curing (Fast curing cycle) two hours.
6. Finishing and polishing.

Mechanical tests utilized to examine properties

Evaluations of the mechanical properties of the prepared nano-composite material were compared with conventional denture base material (heat cure acrylic resin). Including:

Transverse strength
Specimen design

The specimens used were prepared as described with dimensions (65mm X 10mmX 2.5mm ± 0.2mm), Figure (1). Six specimens of each concentration make a total of 24specimens for measurements of transverse strength. All the specimens were immersed in distilled water at 37°C for 48 hours before being tested according to (ADA No. 12, 1999).

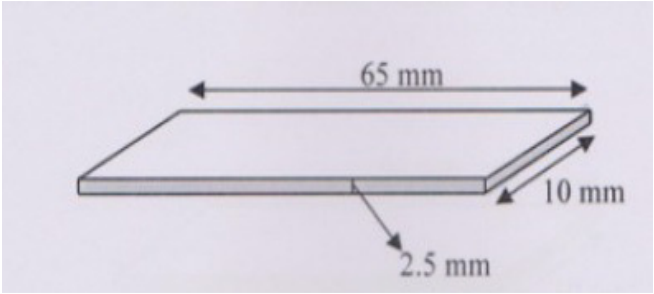

Figure 1. Transverse strength test specimen dimension.

Testing procedure

The test was performed using universal testing machine (WDW- 200E), each specimen was positioned on the bending fixture which consist of two parallel supports (50mm apart), the maximum load was 50Kg and the load applied with across heads speed of 1mm/ min by a rod placed between the supports making deflection until fracture occurs. Transverse strength was calculated using the following equation:

$$T = \frac{3PL}{2bd^2} \ (ADA\ specification\ No. 12, 1999)$$

Where:

T: Transverse strength (N/mm^2); P: Maximum force exerted on samples (N); L: Distance between the supports; b, d: The width and depth of samples (mm) respectively.

Impact Strength Test

Specimen design

The specimens used were prepared as described with dimensions (80mmX 10mm X 4mm ± 0.2mm), international standard ISO. 179. 2000 for unnotched specimens figure (2). Six specimens of each concentration were prepared make a total of (24) specimens for impact strength measurements. Specimens tested after being conditioned in distilled water at 37°C for 48 hours.

Figure 2. Impact strength test specimen dimension.

Testing procedure

Impact strength test was conducted following the procedure given by the ISO 179 with charpy type impact testing instrument. The specimen was supported horizontally at its ends ad struck by a free swinging pendulum which released from a fixed height in the middle. A pendulum of 2 joules testing capacity was used. The scale reading gave the impact energy absorbed to fracture the specimen in joules when struck by a sudden blow. The charpy impact strength of unnotched specimen was calculated in KJ/mm^2 as given by the following equation:

$$Impact\ Strength = \frac{E}{b.d} \times 10^3$$

Where: E: The impact energy in Joules; b, d: Width and thickness, respectively.

Surface Hardness Test

Test Specimens

Specimens of acrylic resin were prepared with a dimension dimensions (65mmx 10mmx 2.5±0.1mm) figure (3). Six specimens of each concentration make a total of 24 specimens for testing. Specimens were stored in distilled water 37°C for 48 hours before being tested (ADA specification No. 12, 1999).

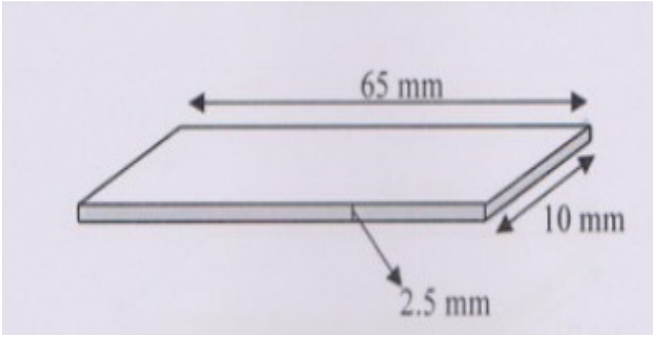

Figure 3. Surface hardness test specimen dimensions.

Testing procedure

Surface hardness was determined using druometer hardness tester from type (shore D) that was fabricated by TIME group INC company according to American National standard/American Dental Association (ANS/ADA) No. 12, 1999 which is suitable for acrylic resin material. The instrument consists of blunt-pointed indenter 0.8mm in diameter that tapers to a cylinder 1.6mm. The indenter is attached to a digital scale that is graduated from 0 to 100 units. The usual method is to press down firmly and quickly on the indenter and record the maximum reading as the shore "D" hardness, measurements were taken directly from the digital scale reading. Three measurements were done on different areas of each specimen (the same selected area of each specimen), and an average of three reading was calculated.

RESULTS

The mean value and standard deviation of transverse strength, impact strength and surface hardness tests are summarized in Table (2, 3 and 4). The statistical analysis revealed that the transverse strength of 1% Li_2SiO_3 are the highest value between tested groups. The results are shown in table (2) and figure (4).

Table 2. Mean, standard deviation and error of transvers strength of control and different percentage of nano- lithium silicate

Static	Control	0.5% Li_2SiO_3	1% Li_2SiO_3	1.5% Li_2SiO_3
Mean	66.02	85.7858	88.176	85.84
SD±	9.714	4.385204	9.836487	10.739
SE±	4.344	1.961123	4.399011	4.80266

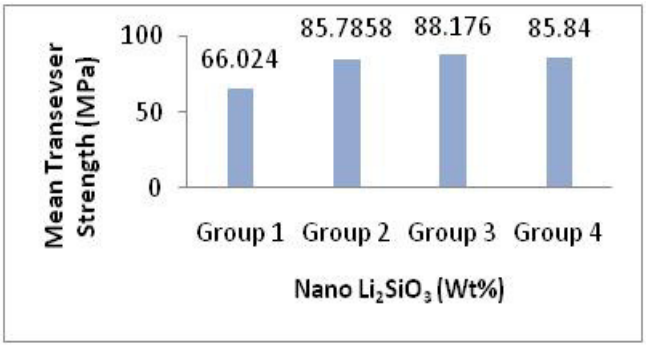

Figure 4. Histogram of transverse strength with means values of the control and tested groups.

The results of impact strength test showed that the addition of modified acrylic with nano-Li_2SiO_3 increased the value of the impact strength compared to control group, 1wt% group has the highest impact strength Table (3) and Figure (5)

Table 3. Mean, standard deviation and standard error of impact strength of control and different percentages of nano-lithium silicate

Static	Control	0.5% Li_2SiO_3	1% Li_2SiO_3	1.5% Li_2SiO_3
Mean	5.14	6.04	7.5	6.05
SD±	0.723187	1.124389	3.066961	1.5850
SE±	0.32341	0.502842	1.371587	2.70564

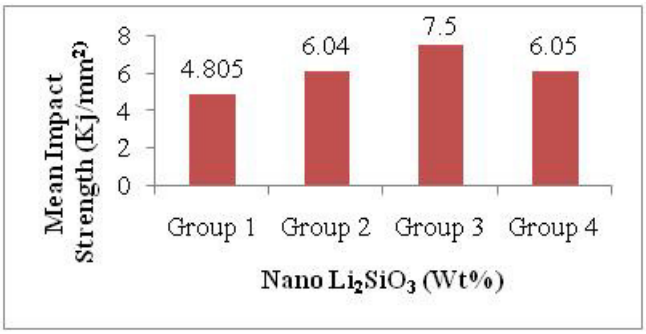

Figure 5. Histogram of impact strength with mean values of the control and tested groups.

In this study, the higher hardness is obtained by adding 1.5% of lithium silicate Nano-fillers, as shown in Table (4) and Figure (6)

Table 4. Mean, standard deviation and of hardness test of control and different groups of nano-lithium silicate

Static	Control	0.5% Li_2SiO_3	1% Li_2SiO_3	1.5% Li_2SiO_3
Mean	80.27	83.32	83.82	84.152
SD±	1.35	1.380	8.044	8.04

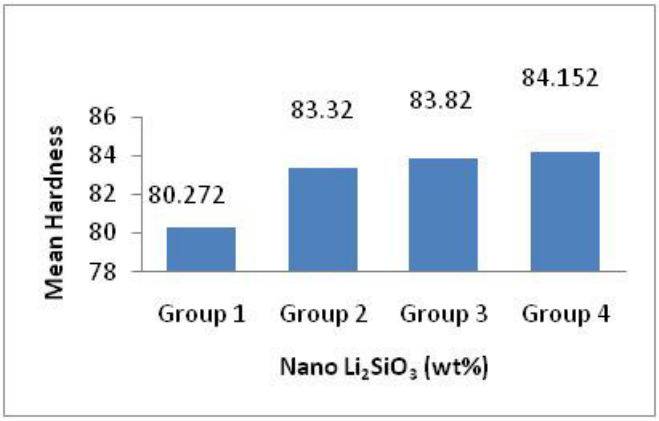

Figure 6. Histogram of hardness with mean values of the control and tested groups.

DISCUSSION

In relevance to the studied parameters, there are no previous researches/studies studying the mentioned parameters.

In this study, nano- Li_2SiO_3 was used in a concentration of 0.5%, 1% and 1.5% to added acrylic resin. The transverse strengths of the tested groups were measured using 3-point bending test. The impact strength was also measured using Charpy tester to determine whether adding nano- Li_2SiO_3 had an effect on the impact strength of the acrylic or not. Also, surface hardness was measured using a digital shore "D" hardness druometer.

Flexural failure of denture base resins is considered the primary mode of clinical failure (Débora et al., 2007). The flexural strength test is thought to be useful in comparing denture base materials because it reflects the complex stresses applied to the denture during mastication and it provides an indication of a materials' rigidity (Mohamed et al., 2016; Ban and Intisar, 2014). This increase in the transverse strength may be due to good distribution of the nano- size particles which enable them to enter and fill the spaces between polymeric chains resulting in increased interfacial shear strength between the nanoparticles and polymeric chains which improve the transverse strength (Mohammed et al., 2016). A gradual decrease in flexural strength was observed in specimens in 1.5% Li_2SiO_3 NPs. It can be attributed to the degree of nanoparticles dispersion in the PMMA resin matrix and the chemical composition of the acrylic resin material used in the study. From this study it could be believed that the polar interactions between the nanoparticles and C=O of polymer matrix (weak interactions) are adequate at low concentrations that results in improving the flexural strength. At higher concentrations, nanoparticles may also act as impurities of polymerization that causes decrease in degree of cure. Hence, more amount of unreacted monomer may be left

over within the matrix that results in decreasing the flexural strength (Rama, 2017).

Impact is defined as the resistance of material to rapidly applied load. The purpose of impact testing is to measure an object's ability to resist high- rate loading (Narinderpal, 2009).

1wt% group has the highest impact strength, that related to good bonding between the matrix and the additive which could be due to interfacial shear strength between the additive and the matrix (Hanan, 2013). While increasing the percentage of modified nano- Li_2SiO_3 lowered the impact strength was attributed to nanoparticle agglomeration. Nanoparticles have high surface energy due to the high specific surface area, and tend to stick together and agglomerate (Majid et al., 2014).

Hardness is defined as the resistance of a material and its ability to abrade opposing dental structures (Gagan and Aparna, 2013). Strength, proportional limit and ductility are some of the properties associated with the hardness of materials. Hardness is a commonly used method to investigate factors that affect the degree of conversion of resins and to characterize mechanical qualities of a polymer due to the simplicity of specimen preparation and test method in addition to the availability of the equipment (Naeim et al., 2014). A dental prosthesis should be reasonably hard to resist surface deformation and fracture (Sheeba et al., 2012). In this study, the higher hardness is obtained by adding 1.5% of lithium silicate Nano- fillers, this is related to the high hardness and brittleness that have these particles as compared with PMMA matrix (Ruaa et al., 2017).

CONCLUSION

Within the limitations of this study, it was concluded that incorporation Li_2SiO_3 nanoparticles into acrylic resins can Positively affects the flexural strength, impact strength and hardness of the final products and this effect is directly correlated with the concentration of nanoparticles.

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