International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 4 Issue 6, June-2015, pp: (158-163), Impact Factor: 1.252, Available online at: www.erpublications.com

Effects of Al_2O_3 and SiO_2 Nanoparticles on Flexural Strength of Heat Cured Acrylic Resin

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Abstract: In this study, the effect of addition Al_2O_3 and SiO_2 nanoparticles with weight percentage of 1% and 3% to flexural strength of heat cured acrylic resin were investigated. Al_2O_3 and SiO_2 nanoparticles were mixed with polymer of heat cured acrylic resin. The rectangular acrylic resin specimens (60 x 12 x 4 mm) were prepared according to ISO 1567 standard. Fifty specimens randomly divided into 5 groups of 10 each according to types and concentrations of nanoparticules. Group 1. Acrylic resin without nanoparticle (Control group), Group 2. Acrylic resin with 1% Al_2O_3 nanoparticles, Group 3. Acrylic resin with 3% Al_2O_3 nanoparticles, Group 4. Acrylic resin with 1% SiO_2 nanoparticles, Group 5. Acrylic resin with 3% SiO_2 nanoparticles. All specimens were stored in distilled water at 37 ^{o}C for 48 hours. The flexural strength was measured by a three-point bending test using a universal testing machine at a crosshead speed of 5 mm/min. Data were analyzed using one-way ANOVA and Tukey HSD tests ($p<0.05$). One-way analysis of variance showed a significant difference between mean values of flexural strength ($P=0.000$). Tukey HSD test revealed that Al_2O_3 and SiO_2 nanoparticle addition decreased the flexural strength of the acrylic resin specimens ($p<0.05$).

Keywords: PMMA Acrylic Resin, Al_2O_3 Nanoparticle , SiO_2 Nanoparticle, Flexural Strength.

Introduction

Acrylic resins are mostly used as denture base material in dental practice. These are available in different forms according to the polymerization reaction as heat cure acrylic resin, rapid cure auto polymerizing acrylic resin, light cure resin and specialized form resins used for microwave processing. These materials have adequate strength to withstand the masticatory forces, maintains the dimensional stability, adequate resiliency, biocompatibility and high polishability [1].

Manufacturers traditionally reinforce polymers with micrometer-size fillers to gain higher strength and stiffness, to improve solvent or fire resistance, or simply to reduce cost. However, these microfillers also impart several drawbacks such as brittleness and opacity. Nano-composites with at least one dimension less than 100 nm provide a new way to overcome the limitations of traditional composites [2].

Reinforcement with metal fillers such as silver and aluminum powder improved some physical and mechanical properties of acrylic resin while addition of silver, copper, and/or aluminum in the form of powder to the resin improved its thermal conductivity, polymerization shrinkage and water sorption [3].

There are many studies concerning with nanoparticle reinforced acrylic resins. According to these studies nanosilver addition increased compressive strength and thermal conductivity but decreased tensile strength of acrylic base [4]. 0.2wt% AgNPs didn't significiantly decreased tensile strength while adding 2wt% AgNPs significiantly decreased tensile strength. 0.2 and 2wt% AgNPs adding increased the compressive strength of acrylic resin. But increasing AgNPs concentration from 0.2 to 2wt% didn't increased significiantly compressive strength [5].

1wt% and 2wt% Al_2O_3 nanoparticles addition increased the mean flexural strength of acylic resin while 3wt% Al_2O_3 nanoparticles addition decreased the mean flexural strength of acrylic resin [6]. According to statistical results the difference between mean flexural strengths of groups added 0.5wt, 1wt% Al_2O_3 and mean flexural strength of control group was not significiant. While addition 2.5wt% Al_2O_3 increased mean flexural strength significiantly , addition 5wt% Al_2O_3 decreased mean flexural strength of heat cured acrylic resin significiantly [7].

In this study, the effects of Al_2O_3 and SiO_2 nanoparticles on the flexural strength of heat cured acrylic resin were investigated.

Materials and Methods

In this study acrylic resins reinforced with 1wt%, 3wt% Al_2O_3 and 1wt%, 3wt% SiO_2 nanoparticles were used. The heat cured acrylic resin as resin was used. The materials used in this study were given in Table (1). Al_2O_3 nanoparticles and SiO_2 nanoparticles were mixed with polymer of heat cured acrylic resin for 30 min. using a mechanic mixture and then for 5 min. amalgamator for a good distribution.

Test specimens were prepared according to ISO 1567 standard. The dimensions of rectangular specimens were 60 x 12 x 4 mm. Five group specimens were prepared.

Group 1. Acrylic resin without nanoparticle (control group),
Group 2. Acrylic resin with 1wt% Al_2O_3 nanoparticles,
Group 3. Acrylic resin with 3wt% Al_2O_3 nanoparticles,
Group 4. Acrylic resin with 1wt% SiO_2 nanoparticles,
Group 5. Acrylic resin with 3wt% SiO_2 nanoparticles.

Fifty wax specimens were composed. The dimensions of wax specimens were 60 x 12 x 4 mm. Specimens were invested with dental plaster. Flasks were placed to dewax in conventional water bath. They were opened and cleaned to remove traces of wax. Specimens were prepared by hand mixing 2.2 g of PMMA powder with 1.1 mL of methyl methacrylate monomer using a powder to monomer ratio of 2:1 Hydraulic pressure was maintained for 5 minutes before placing the assembly in to boiling water. The conventionally molded, heat-cured acrylic resin was placed under compression in 100 ^oC water for 30 minutes. The specimens were removed from the flasks after curing. All the specimens were grounded with 400 grit size silicon carbide paper. Before test procedure the storage of specimens indistilled water at 37 ^oC for 48 hours was carried out (Fig. 1)

The three-point bending tests were conducted. Tests were performed using an universal test machine at 5 mm/min crosshead speed as shown in Fig. 2. Maximum flexural load values were recorded during the tests. The flexural strengths of specimens were calculated using Equation 1. Where σ (MPa) is flexural strength, F (N) is flexural load, L (mm) is span length, b (mm) is width of specimen, d (mm) is thickness of specimen.

$$\sigma = \frac{3.F.L}{2.b.d^2} \qquad \text{Eq.1.}$$

Statistical Analysis

Statistical analysis was performed with Kolmogorov-Smirnov test of normal distribution an One-way ANOVA followed by Tukey's honestly significant difference (HSD) test with a general linear model procedure in SSPS 17.0 (SPSS Inc., Chicago, USA). One-way ANOVA followed by Tukey's HSD test wasused within each acrylic resin group to compare effectiveness of different reinforcements. A significance level of 0.05 was used for statistical tests.

Results and Discussions

In this study the comparison of flexural strength was done between the control group and the specimens containing different concentrations of Al_2O_3 and SiO_2 nanoparticles. Maximum load values were determined with three-point bending test. The mean flexural strengths of five group specimens calculated and deviation values were determined with statistical analysis. These values were shown in Table (2).

One-way analysis of variance showed a significant difference between mean values of Flexural strength (P=0.000). Statistical analysis using the posthoc Tukey HSD significant differences test revealed that although Al_2O_3 and SiO_2 nanoparticle addition decreased the flexural strength of the acrylic resin specimens.

Highest mean flexural strength was observed in Group 1, while the lowest was seen in Group 2 and Group 4 (Fig. 3).

Many studies were performed to analyse effects of different nanoparticles on properties of acrylic resins. Hamedi-Rad et al. [4] investigated the effect of adding nanosilver paticles to PMMA to determine thermal conductivity, compressive strength and tensile strength. 5wt% Nanosilver was added to PMMA. Cylindrical and rectangular shaped samples were tested. Test results showed that nanosilver addition increased compressive strength and thermal conductivity but decreased tensile strength of acrylic base. Ghaffari et al. [5] studied the effect of adding AgNPs to PMMA to assess tensile and compressive strengths of acrylic resin. 0.2 and 2wt% AgNPs were mixed with heat-curing acrylic resin. Test results showed that adding 0.2wt% AgNPs didn't significiantly decreased tensile strength while adding 2wt% AgNPs significiantly decreased tensile strength. 0.2 and 2wt% AgNPs adding increased the compressive strength of acrylic resin. But increasing AgNPs concentration from 0.2 to 2wt% didn't increased significiantly compressive strength. Shirkavand and Moslehifard [8] investigated the effect of TiO_2 nanoparticles on the tensile strength, modulus of toughness, elastic modulus, morphology and structure of acrylic resin. Andreotti et. al. [9] analysed the effects of addition TiO_2, ZnO and $BaSO_4$ nanoparticles on color stability, microhardness and flexural strength of acrylic resin. Harini et al. [10] evaluated the effect of TiO_2 nanoparticles having different concentrations to flexural strength of PMMA. Safi [11] investigated the effect of Al_2O_3, SiO_2 and TiO_2 nanofillers on glass transition temperature, E-modulus, coefficient of thermal expansion of acrylic resin.

Jasim and Ismail [6] investigated the effect of Al_2O_3 nanoparticles on transverse strength, surface roughness, surface hardness, thermal properties, water sorption and water solubility of acrylic resin. 1wt%, 2wt% and 3wt% Al_2O_3 to heat cured acrylic resin and determined flexural strengths of these specimens. 1wt% and 2wt% Al_2O_3 nanoparticles addition increased the mean flexural strength of acylic resin while 3wt% Al_2O_3 nanoparticles addition decreased the mean flexural strength of acrylic resin. Vojdani et al. [7] performed the flexural tests of specimens added 0.5wt%, 1wt%, 2.5wt% and 5wt% Al_2O_3 to heat cured acrylic resin. According to statistical results the difference between mean flexural strengths of groups added 0.5wt, 1wt% Al_2O_3 and mean flexural strength of control group was not significiant. While addition 2.5wt% Al_2O_3 increased mean flexural strength significiantly , addition 5wt% Al_2O_3 decreased mean flexural strength significiantly.

Possible explanations for this reduction in the strength could be: a decrease in the cross-section of the load-bearing polymer matrix; stress concentration because of too many filler particles; changes in the modulus of elasticity of the resin and mode of crack propagation through the specimen due to an increaed amount of fillers; void formation entrapped air and moisture; incomplete wetting of the fillers by the resin; and the fact that HA and Al_2O_3 nanoparticles acts as an interfering factor in the integrity of the polymer matrix [12].

In this study the mean flexural strength of control group was the highest. The addition Al_2O_3 and SiO_2 nanoparticles 1wt% and 3wt% decreased mean flexural strength value of acrylic resin. The addition Al_2O_3 and SiO_2 nanoparticles 1wt% decreased this value more than Al_2O_3 and SiO_2 nanoparticles 3wt%. Because of catalytic effect of Al_2O_3 and SiO_2 nanoparticles as %weight ratio increased deflection of specimen decreased and brittleness increased so mean flexural strength value decreased.

Conclusions

In this study the effects of Al_2O_3 and SiO_2 nanoparticles on flexural strength of heat cured acrylic resin were investigated experimentally. Based on the results, the following conclusions were made:

1. The mean flexural strength of control group was the highest in all groups.
2. Al_2O_3 and SiO_2 nanoparticles decreased the mean flexural strength of heat cured acrylic resin.
3. The addition Al_2O_3 and SiO_2 nanoparticles 1wt% decreased this value more than Al_2O_3 and SiO_2 nanoparticles 3wt%.

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Table (1): The materials and manufacturers

Material	Manufacturer
Heat cured acrylic resin	Meliodent Heraeus Kulzer, Germany
Al_2O_3 nanopowder (99.5% pure, powder size 40-50 nm)	MKNANO, Canada
SiO_2 nanopowder coated with silane coupling agent (99.5% pure, powder size 15 nm)	MKNANO, Canada

Table (2). Mean flexural strength and deviation values of groups

Groups	Mean Flexural Strength (MPa)	Standard Deviation
Group 1(without nanoparticle)	97,38	7,00
Group 2(1wt% Al_2O_3 nanoparticle)	81,28	17,32
Group 3 (3wt% Al_2O_3nanoparticle)	89,30	15,02
Group 4 (1wt% SiO_2nanoparticle)	71,65	8,32
Group 5 (3wt% SiO_2nanoparticle)	81,52	8,83

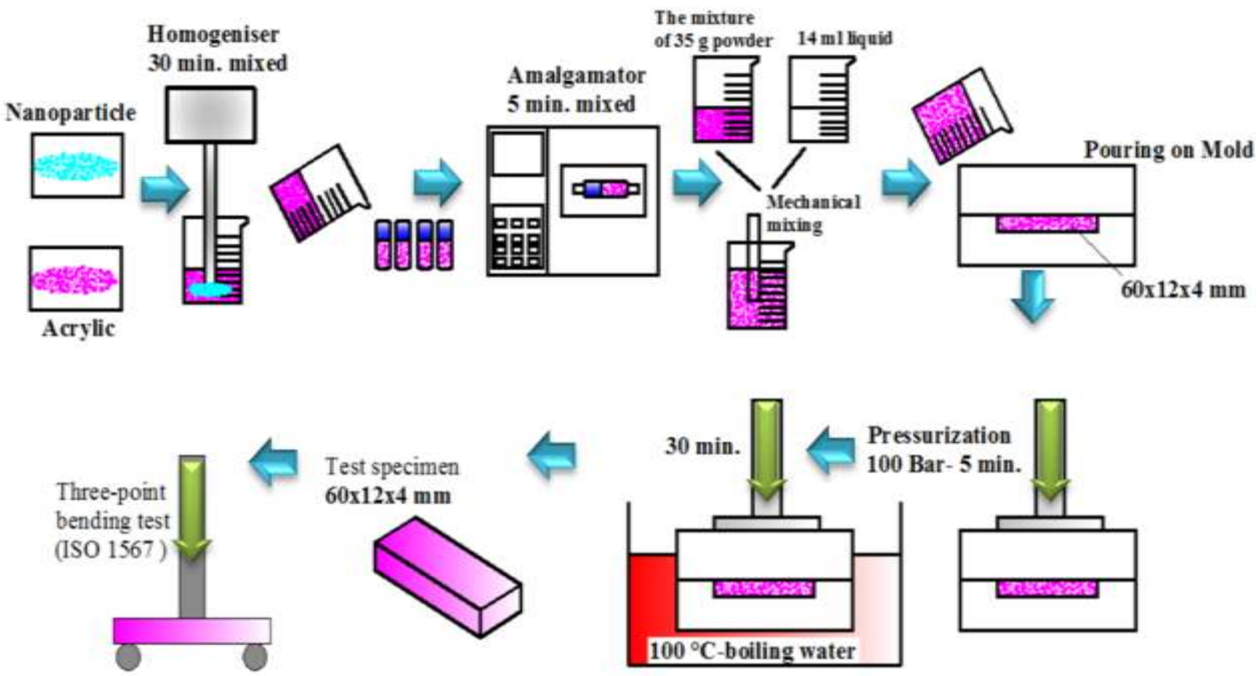

Fig. 1: Manufacturing process.

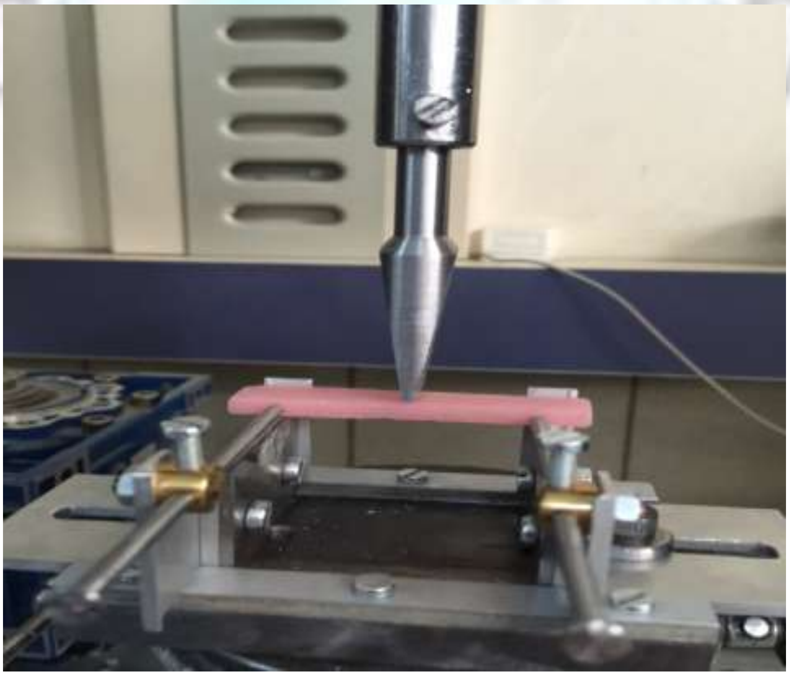

Fig. 2: Universal test machine.

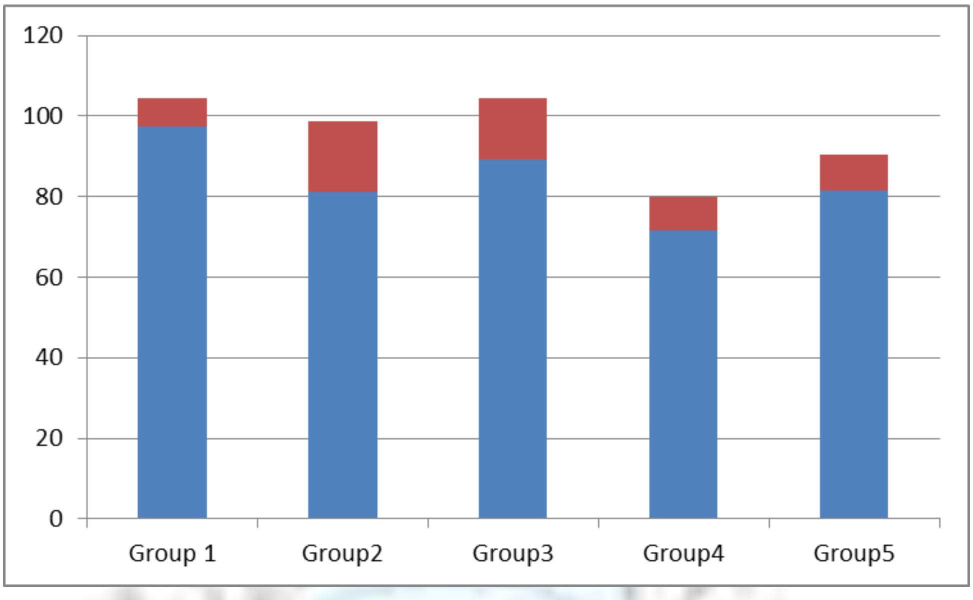

Fig. 3: The graphics of flexural strength of five groups.