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Evaluation of Titanium Dioxide Nano-Fillers Incorporation on Transverse Strength of Heat Cured Acrylic Resin

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Abstract

Denture bases made of commonly used acrylic polymers have weak mechanical qualities. This investigation sought to determine how adding titanium dioxide nanoparticles (TiO2) to acrylic denture base materials might affect their transverse strength (Poly Methyl Mehta Acrylate PMMA). A controlled group and experimental group of percentages and 2%wt of TiO2 powder was added to monomer and mixed by probe sonication appliance. SEM was performed for the Titanium Dioxide (TiO2) and the composite of (PMMA and TiO2 NPs) that showed diameter of TiO2 NPs (25.7 nm) and good distribution of NPs in PMMA. The outcomes demonstrated progress in the Transverse Strength of Heat Cured Acrylic Resin.

Acrylic is still commonly used today despite having weak mechanical characteristics since it is the material of choice for denture bases[1]. Acrylic may be treated with various reinforced materials to improve its features in order to address this issue. Metallic reinforcers, carbon-graphite fiber, aramid or glass fiber, are among the materials suggested in these enforcement measures[2].
NanoParticless, such as titanium dioxide or zinc oxide, with some more forms, are widely employed nowadays. Because of the tiny particle dimensions, large surface areas, and strong interfacial connection between the matrix of the polymer (organic segment) and the NPs (inorganic segment), the interconnection between these additives and denture base poly methyl methacrylate can enhance various physical,mechanical and optical qualities [3].
The characteristics of polymer nanoparticle mixtures may govern by different factors among them is the nanoparticles characteristics as their size, shape, and crucially, how they interact with the polymer matrix [4].
TiO_2 is frequently utilized as an integrated filler because of its inexpensive cost, chemical stability, and lack of toxicity [5].

Material and Methods

Specimen preparation and grouping

The denture base materials were chosen from among conventional type of heat cured PMMA (polymethyl methacrylate) which comes in two components liquid monomer and powder (Vertex, Netherlands) acrylic resins. Separately, 0.72 g of TiO_2 NPs was added to 18 ml of heat-activated monomers.

For three minutes, the monomer-NPs mix was sonicated by ultrasonic device (Sonipre p150, England, at 120 watts and 60 kHz) to make sure that each NP was evenly distributed throughout the monomers. The necessary amount of TiO_2 NPs and acrylic resins were weighed using an ele digital balance (Sartorius, Germany, with an accuracy of 0.0001 g). In accordance with the manufacturer's recommendations, the mix of the -monomers and TiO_2 NPs- was manually transferred right away with PMMA powders (35.28 g) to prevent of particle sedimentation and phase separation. Approximately 10 minutes mixing time later, the mixture was ready for handling and had taken on the consistency of dough. To achieve a 2.0 wt.% NPs ratio in the nanocomposite, the P/L ratio was kept at 2.2:1(35.28 g/18 ml) according to manufacturer's instruction (2.2 g of powder polymer to 1ml liquid monomer).

Figure (1): specimen for control group

A 2.0 weight percent NPs concentration was found to be sufficient for the resulting nanocomposite with increased strength. The mixture was placed into a mold measured (65 x 10 x 3) mm to produce specimens for transverse testing .The specimen were prepared with CNC laser machine (CO_2 laser ,china). in order to ensure that every specimen has the same measurements. The mold was then sealed and set in a hydraulic press at 15 MPa pressure. Then a type IV dental stone was flasked using a compression process (Elite Stone, Zhermack, Germany). After that, the flasks were snugly fastened and kept under pressure and bench-cured for half an hour to ensure optimal monomer and polymer penetration. Then flasks were submerged in a water bath with a thermostat at room temperature, then when temperature reached 74 °C, it maintained for1.5 hours, after that it increased to 100 °C for half an hour. When the curing cycle was finished, the flask was left to cool outside the bath. First of all flasks were left for bench-cooling for 30 minutes then submerged under tap water for 15 minutes. After using a carbide bur to shape the samples, they were polished using slurry of coarse pumice. Finally, a total of 24 specimens grouped into two groups, 12 samples of transverse strength for each group. According to the ADA specifications, for conditioning al the specimens were kept in distilled water for 48 hours at 37°C before testing.

Calculation of Transverse Strength

Using a universal testing equipment (ASIAN Test Equipments, Micronix Instruments, India), load till fracture was determined by the transvers strength or the three-point bending test in accordance with ISO 178 to evaluate transverse strength (Fig. 2).. After that, specimens were mounted on a three-point flexure device with a 50-mm support span. With a crosshead speed of 5 mm/min, in the center of the sample; the load was directed until the specimen cracked recording the load of fracture Each specimen's transverse strength values were calculated using a formula.

$$TS = \frac{3wl}{2bd^2}$$

Here TS (in MPa),is the transverse strength while the fracture load in (N) is w in the formula, the space from one support to the other in specimen testing is l, width and thickness are b and d respectively.

Figure (2). Universal Testing Machine and the specimen in the test

Scanning Electron Microscope

The surface morphology of the TiO_2 film plays a significant role in many applications; scanning electron microscopy is a suitable tool for studying the film's morphology as well as a composite specimen.

Results and Discussion

Scanning Electron Microscope Test

Result of SEM test shown in figure (3) reveals that the surface is coated in films of nanoparticles with an average diameter of 25.7 nm that have the appearance of sponges or flowers and are uniformly dispersed throughout the whole surface. The observed surface shape has a significant influence on the optical properties of the thin film by providing a large surface area per unit volume, which results in good absorption while figure 4 of the SEM micrograph demonstrated well surface

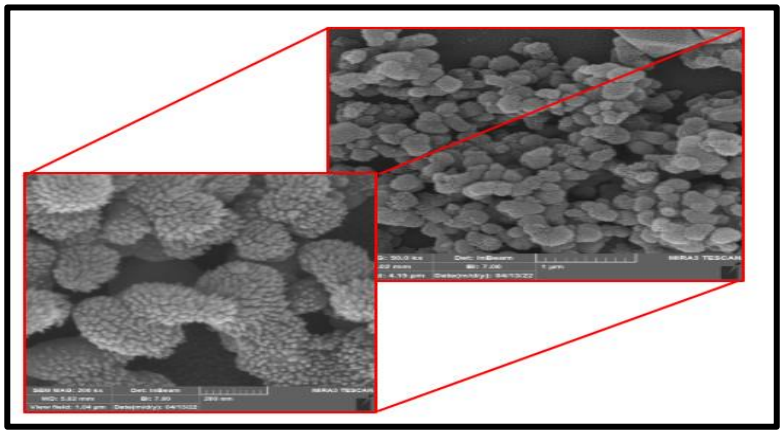

Figure (3). SEM images of TiO2 thin film deposited at a room temperature

properties with nanotitanium concentration. Since no significant agglomeration was discovered, a uniform dispersion of particles was expected. According to this SEM analytical investigation, the matrix of polymer was filled with nanoparticles at a concentration of 2%, which prevented crack development and produced a stronger material. The value of the nanoparticles' additive content is demonstrated by the uniform filling of the inter-polymeric chain gaps after the nanoparticles were uniformly dispersed into the resin matrix. This is also consistent with Thakur Eat Al and Alamgir's research [6, 7].

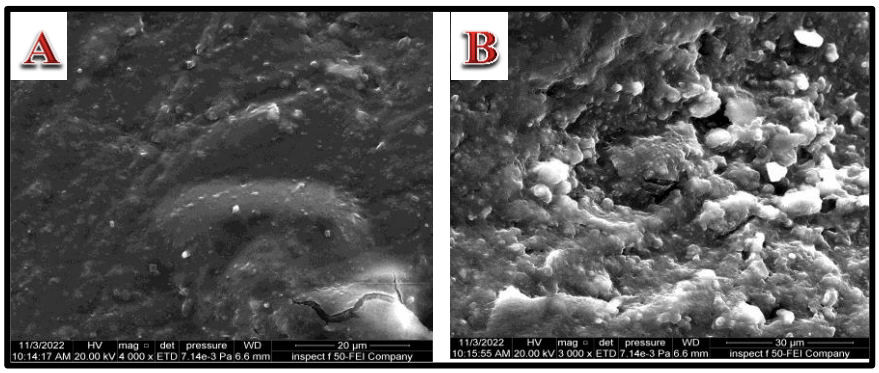

Figure (4). FESEM of Composite material (PMMA+TiO2 NPS) A; at 20µm B; at 30µ

Transvers Strength Test

The flexural strength of PMMA specimens incorporated with TiO_2 nanofillers was assessed using the 3-point bend test, as shown in Figure (5). The mean transverse strengths (96.178 Mpa) is higher than the control (84.954 and N/mm2).

According to the results of the t-test, table (1), the P value of 0.001 revealed a significant difference between the tested groups.

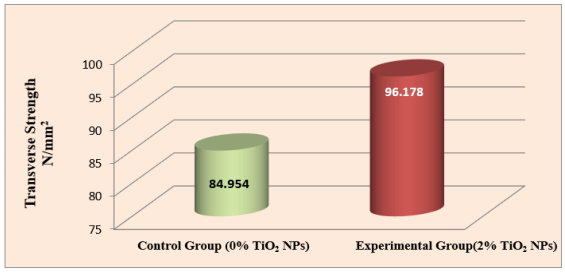

Figure (5). Bar Chart of Transverse Strength Mean Value (N/mm2)

Table (1) Mean Values, Standard Deviation, Standard Error, and Independent T-test Results of Transverse Strength in (KJ/mm2)

	Control Group (0% TiO2 NP)	Experimental Group (2%TiO2 NP)
NO. of Specimens	10	10
Mean	84.953	96.222
SD	7.178	3.895
SE	2.269	1.231
T-value	-4.636	
P-value	0.001	
Significance	High	

According to the results of our study, 2% titanium dioxide increasesd the transverse strength of PMMA, this is consistent with the findings of Thakur and his team, who discovered that adding titanium dioxide nanoparticles to a PMMA matrix at a concentration of 2.5% increased transverse strength. This increase in transverse strength was attributed to uniformly dispersed, tiny filler particles. The increased fracture resistance of PMMA is a result of this. By using up to 2.5% of titanium dioxide nanoparticles, the strength was increased. after which the strength fell. This response is likewise in line with what we observed when we added 3% titanium dioxide [8].

Saleh et al. (2017) evaluated the impact of introducing several types of nanoparticle elements on the transverse strength and modulus as well as shear stress, and flexural modulus. The flexural strength and shear stress of the PMMA nanocomposite materials improved with the addition of fly ash, fly dust and zirconia nanoparticle powders. Additionally, it can be seen from the results that these two properties peak at a volume fraction ratio of 2% when compared to pure PMMA. The causes of this behavior include the high interfacial shear strength between the PMMA matrix and nanoparticles which was explained by forming supramolecular or due to cross-link bonding which might prevents the initiation or propagation of cracks within the composite. Additionally, the crack's ability to propagate can be altered by the PMMA matrix's and nanoparticles' ability to form a strong bond [9].

The results agree with those obtained by Karci et al. (2018), who found that 3 weight percent and 5 weight percent of TiO_2 np Researchers found that reinforcements with 3 wt.% and 5 wt.% TiO_2 NPs had reduced flexural strength values due to an apparent drop in the bending strength of PMMA and an inhomogeneous distribution of the particles that caused agglomeration [10].

The outcomes of adding 1% of TiO2 NP are in agreement with those of Ahmed and his associates, who concluded that adding TiO2 NPs in 1% and 5% had a cause of deterioration of the flexural strength of acrylic denture base, conventional and high impact types. It was concluded that the type of acrylic and the quantities of nanoparticles all had an impact on how TiO2 Nps affected the flexural strength of PMMA [11].

Tandra et al.'s (2018) study, which contradicts our findings, saw a rise in the flexural strength value in the 1 weight percent category as opposed to the control group. The increase in surface energy, intermolecular force of attraction, and cross-linking caused by the silanization of TiO2 NPs improved the binding between the resin matrix and the NPs, according to the authors [12].

Azmy et al. (2022) reported that the addition of 3 weight percent of TiO_2 nanoparticles increased the flexural strength; however, their results did not match ours. The well-dispersed TiO2 nanoparticles in the PMMA matrix at low concentrations were blamed by the scientists for their disparity. Strong interfacial contacts between the PMMA matrix and the nanofiller decrease the slip of the polymers's molecules as TiO2 enters the matrix. [13].

The results showed that adding fillers might strengthen the denture base and increase its flexural strength. This was accomplished by improving the bond between the base material and the reinforcement. The reduction in free space between polymer chains and the addition of fillers resulted in the filling of these spaces and the attraction of resin molecules, which caused polymer chains to form more intricate network chains during the curing process, which contributed to the increase in

flexural strength [14].

Conclusion

1. SEM results showed good dispersion of TiO_2 NPs in polymer matrix
2. Significantly improved transverse strength of PMMA denture base resin modified with 2% of titanium dioxide nanoparticles.

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