



Effect of Tantalum Oxide Nanopowder on Heat Cure Acrylic Resin Thermal Conductivity and Surface Roughness

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Abstract

The main problem with heat cure acrylic is their poor thermal conductivity and their roughness. This study aims at evaluating the effect of tantalum oxide nanopowder on the thermal conductivity and surface roughness of heat cure acrylic resin. Material and Method: The Intention was to create a total of (60) specimens. Twenty samples were made without additives (control), and 40 had been made with tantalum oxide at two different amounts (1 %, 1.5%). Results: the thermal conductivity tests showed non-significant difference among studied groups. The surface roughness tests showed highly significant difference among studied groups. when tantalum oxide had added to heat cure acrylic at two different amounts (1%, 1.5%). Conclusion: adding tantalum oxide increases the thermal conductivity and decreases the surface roughness of the two experimental groups.

Introduction:

Since the introduction of poly (methylmethacrylate) by Dr. Walter Wright in 1937 (1). PMMA remains the preferred material for dentures base construction (2). Denture fracture is a typical clinical event in prosthodontic care, despite the extensive usage of PMMA in prosthetic dentistry (3). Acrylic resin denture base material is considered as the leading material for construction of dentures today. This may be related to its

advantageous properties like good esthetic and biocompatibility. However, it still has some drawbacks including poor mechanical properties (4). The glossy, nonporous surface of the acrylic resin makes it less likely that dirt, dust, and plaque will stick to it (Harrison et al., 2004) (5). The roughness of the denture base has an effect on the oral tissues that come into contact with it. caries, periodontal disease, and denture stomatitis

are caused by microorganisms that cannot make it in the mouth unless they colonize a nonshedding oral surface. (Morgan and Wilson, 2001) (6). Silver and platinum nanoparticles, both strong antibacterial agents, are often used in denture base materials. Researchers demonstrated that increasing the surface hydrophobicity of polymethyl methacrylate with metal nanoparticles including titanium oxide, ferric oxide, and silver decreased biomolecular adhesion (7).

Tantalum pentoxide, also known as tantalum(V) oxide, is the inorganic compound with the formula Ta_2O_5 (8) It is a white solid that is insoluble in all solvents but is attacked by strong bases and hydrofluoric acid. Ta_2O_5 is an inert material with a high refractive index and low absorption (i.e. colourless), which makes it useful for coatings (9). It is also extensively used in the production of capacitors, due to its high dielectric constant. Tantalum occurs in the minerals tantalite and columbite (columbium being an archaic name for niobium), which occur in pegmatites, an igneous rock formation (10). This investigation intends to determine the effects of tantalum oxide on thermal conductivity and Surface roughness Characteristics of Heat-Cured acrylic resin.

Materials and Methods

Preparation of specimens

Thermal conductivity test

Thermal conductivity test: according to ISO 179 (11) the designs were created with dimensions of 40 mm diameter x 2,5 mm thickness (MUKHLIF, O.R, 2015) as shown in Figures (1), (2), and (3). Ten specimens for the thermal conductivity test were made for the control group and twenty specimens for each experimental group.

Surface roughness test (Ra)

Surface roughness samples measuring 65mm in length, 10mm in width, and 2.5mm in thickness were prepared from acrylic resin. as shown in Fig. (4).

Ten specimens for the surface roughness test had made for the control group and

twenty specimens for each experimental group.

1. Mold preparation

The plastic patterns (thermal conductivity and Surface roughness) were coated with separating material to prepare the stone mould.

The dental stone had been placed in the lowest part of the flask.

The flasks upper half was filled with stone and vibrated before the cover was put on and allowed to set. At that point, the plastic models were inserted until they reached roughly halfway point of their depth.

After the stone has been set, the two halves are separated, the plastic pattern have taken out to make room for the acrylic specimen mould, the separating media is added, and once it has dried, the flask had prepared for packing the acrylic specimen.

2. Specimens fabrication

Used twenty samples from the heat –cure acrylic resin (PROCRYLA,PD) to make the control group specimens utilising the manufacture s recommended 20gm/10ml (powder /liquid) ratio

In contrast, the experiment groups (40 specimens) were made from the same acrylic resin and mixed with various amounts of tantalum oxide (from SKYSPRING Nanomaterials, Inc.) of different concentration (1%, 1,5%)

The necessary quantity of tantalum oxide was measured with electronic balance, deducted from the volume of the polymer, and then combined with the monomer for three minutes in a dry, clean glass beaker using probe sonication.

Following the addition of this combination to the acrylic powder, which was then well blended, followed the manufacturers recommended curing procedure.

Mechanical and physical test:

Before either test was performed, all samples were kept in 37 °c distilled water for 48 hours (12).

Thermal conductivity test:

The ability of a material to conduct or transfer heat is measured by a procedure

called a thermal conductivity test. While the letter 'k' is the most common way to represent this value, the notations ' λ ' and ' κ ' are also acceptable.

- There aren't many uses for polymers because of their poor thermal conductivity, which is why they're typically considered insulators. Recent research, however, has shown that some polymers have thermal conductivity that is on par with poor metals or even silicon. Test specimen and device: Lee's apparatus is used in this test 40 mm diameter x2,5 mm thickness. Fig. (2).

Surface roughness test (Ra)

Ra "is a measure of the irregularity of the finished and polished surface and is measured in micrometers (μm)" (Roughness). If you want to minimize the accumulation of bacteria and give something a glossy finish, you should aim for a surface with a roughness (Ra) of less than 0.2 μm . (Powers and Wataha, 2013). Increasing surface roughness can lead to a deteriorating effect on the hygiene and esthetic of acrylic denture because of enhancing the growth of bacterial plaque and facilitating denture staining (Onwubu et al., 2017) as shown in Figures (5), and (6).

Statistical Methods

Microsoft Excel 2010 was used to create the study's graphs and tables, and IBM SPSS Version 24 was used for the statistical analysis. The results were evaluated and interpreted using the mean, standard deviation, minimum, and maximum as well as tests of statistical significance (Student test) (ttest).

Results:

Thermal conductivity test

Table (1) displays the thermal conductivity test descriptive statistical data (1) Table (2) shows that at the $p > 0.05$ level of significance, there was no difference between the control and treatment groups, based on the results of an ANOVA test.

Surface roughness test (Ra)

Table (3) displays the Surface roughness test descriptive statistical data. The

experimental groups showed highly significant differences in mean values from the control group at both the 1% and the 1.5 % concentrations of tantalum oxide. Table (4) demonstrates that, at the ($p < 0.05$) level of significance, there was a difference between the control and treatment groups, based on the results of an ANOVA test.

Discussion:

Thermal conductivity test

Rate of heat conduction depends on cross-sectional of a specimen of the material over a given time interval is a measure of its thermal conductivity, which is one of the important thermal properties of a dental material. Increasing the value increases thermal conductivity. As can be seen in Table (1), the thermal conductivity value increases when tantalum oxide powders are included in the mix. Adding tantalum oxide powder results in an increase in thermal conductivity that is proportional to the amount added but statistically insignificant when compared to the control group. Table (1). There is an increase in thermal conductivity when thermally conductive particles are embedded within a PMMA matrix; this may be because the particles overlap within the matrix, thereby mitigating the insulating effect of the PMMA matrix. Increasing the filler percentage causes the filler particles to become closer together, which in turn increases the overlapping of the thermally conductive particles, which in turn forms a pathway and permits the transition of heat from one side of the specimen to another (13).

These findings are consistent with those of Marei et al. (1994) (8). based on the hypothesis that the isolating material's thermal conductivity can be improved by incorporating thermally conductive particle into the PMMA matrix. Also, the result of this study agrees with Messersmith et al (1998) (14) who studied the effect of aluminum oxide whiskers on thermal diffusivity of heat cure acrylic resin.

Surface roughness test (Ra)

The glossy, nonporous surface of the acrylic resin makes it less likely that dirt, dust, and plaque will stick to it (Harrison et al., 2004) (15). The roughness of the denture base has an effect on the oral tissues that come into contact with it. Aries, periodontal disease, and denture stomatitis are caused by microorganisms that cannot make it in the mouth unless they colonize a nonshedding oral surface. (Morgan and Wilson, 2001) (16). In this study highly -significant change with different percentages of added Ta₂O₅ nanoparticles and this may be due to that the Ta₂O₅ nanoparticles have very small size, Also, since the outer surface of the nanocomposite is of interest to the surface roughness test and not the inner surface, only a small number of nanoparticles were involved in the surface of the specimens when a small percentage of nanoparticles were added to the acrylic resin. (Al momen, 2000) (17), Consequently, the addition of a negligible amount of nanoparticles to acrylic resin has only a negligible impact on the surface roughness. Therefore, when compared to the control group, the Ta₂O₅ nanoparticles will have little to no effect on surface roughness.

This study's findings are consistent with those of (Kamil and Al-Judy, 2018) when silicon carbide was added to acrylic resin. Also, coincide with the result obtained by (Jasim, and Ismail, 2014) (18) when alumina oxide was added to acrylic resin, but disagree with result obtained by (MAH and Aljafery,2015) when add ZrO₂_ Al₂O₃ nanoparticles to heat cured acrylic resin denture base material(19).

Conclusion:

Adding tantalum oxide increases the thermal conductivity and decreases the surface roughness of the two experimental groups.

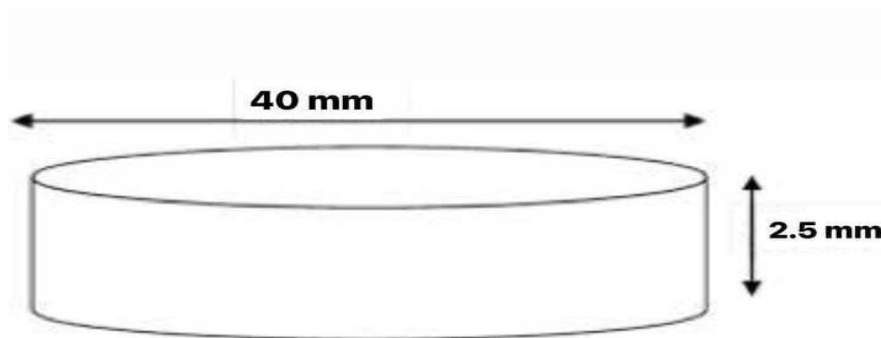


Fig. (1): Thermal conductivity dimensions.



Fig. (2): Thermal conductivity apparatus

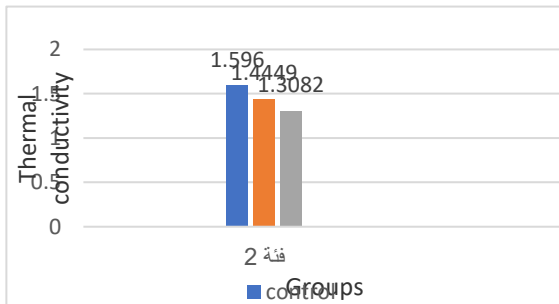


Fig. (3): Bar chart of thermal conductivity test

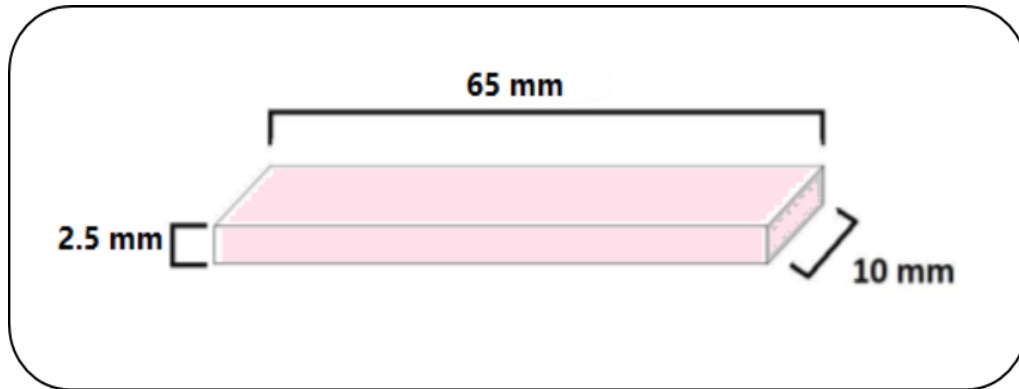


Fig. (4): Surface roughness test specimen dimensions



Fig. (5): profilometer Portable roughness tester.

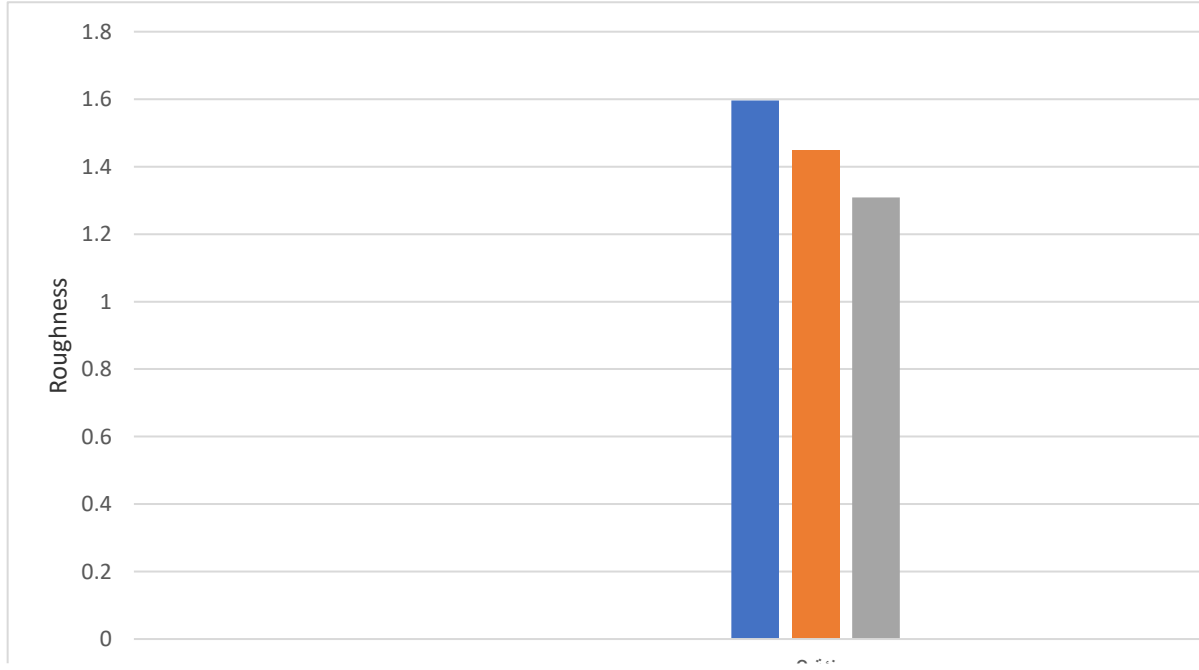


Fig. (6): Bar chart of surface roughness test representing mean values and standard deviation.

Table (1): Descriptive statistics of thermal conductivity test.

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	0.3687	0.3750	0.01186	0.32	0.43
1%	10	0.3948	0.4446	0.01406	0.33	0.45
1.5%	10	0.4017	0.03037	0.00960	0.34	0.46
Total	30	0.3884	0.03931	0.00718	0.32	0.46

Table (2): One way (ANOVA) of thermal conductivity test.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.006	2	0.003	2.111	0.141
Within Groups	0.039	27	0.001		
Total	0.045	29			

Table (3): Descriptive statistics of surface roughness test (μm)

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	1.5960	0.08364	0.02645	1.46	1.76
1%	10	1.4449	0.06916	0.02187	1.32	1.55
1.5%	10	1.3071	0.04917	0.01555	1.25	1.40
Total	30	1.4493	0.13714	0.02504	1.25	1.76

Table (4): One way (ANOVA) of roughness test.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.418	2	0.209	44.124	0
Within Groups	0.128	27	0.005		
Total	0.545	29			

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