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Effect of Tantalum Oxide Nanopowder on Heat Cure Acrylic Resin Impact Strength and Surface Hardness

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Abstract

Background: In elderly patients, fracture of the denture is one of the most common problems. Therefore, in this research, a chemical tantalum oxide was added to test its effect on the extent of increasing the strength of the denture and its ability to withstand fracture.
Objective: To assess how Tantalum oxide affected heat – cured acrylic s impact strength and hardness.
Patients and Methods: The Intention was to create a total of (60) specimens. Twenty samples were made without additives (control), and 40 had made with tantalum oxide at two different amounts (1%, 1.5%).
Results: The impact strength tests showed highly significant difference among studied groups . The hardness test also showed really significant difference between the two groups, the controls and the experiments. when tantalum oxide had added the impact strength and hardness had increase in all concentration.
Conclusion: Denture fracture in elderly patients is the main problem, while when adding this substance, a decrease in the fracture rate was observed when compared with dentures without adding this substance.
Keywords: acrylic resin , polymethylmethacrylate , and tantalum oxide

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Introduction

An acrylic resin is a thermoplastic or thermosetting plastic substance typically derived from acrylic acid, methacrylic acid and acrylate monomers such as butyl acrylate and or methacrylate monomers such as methyl methacrylate.

Since the introduction of poly methylmethacrylate (PMMA) 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 [5].The

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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 [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 2O5 [8].

It is a white solid that is insoluble in all solvents but is attacked by strong bases and hydrofluoric acid.

Ta2O5 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 Impact strength and Surface hardness Characteristics of Heat-Cured acrylic resin.

This study was done in the laboratory and was not applied to the patient, and the additives obtained approval, and good results were obtained like impact strength and surface hardness.

Patients and Methods

Preparation of specimens

Sample description

Impact strength test: according to ISO 179 [11] the designs were created with dimensions of 80*10*4mm (length, width , and thickness, respectively) as shown in Figure (1).

Ten specimens for the impact strength test had made for the control group and twenty specimens for each experimental group.

Surface hardness test : The dimensions of the acrylic resin samples were as follows. Dimensions: 65 mm in length, 10 mm in width, and 2.5 mm in depth as shown in Figure(4). Ten specimens for the surface hardness test had made for the control group and twenty specimens for each experimental group.

Workplace

The work was done at the University of Baghdad, College of Dentistry, Department of Prosthetics, the samples were examined at the University of Technology, Department of Materials Engineering.

Duration of work

The work period took five months from 1/12/2022 to 1/5/2022

Mold preparation

The plastic patterns (for surface hardness and impact strength) were coated with separating material to prepare the stone mould.

The dental stone had 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 the halfway point of their depth.

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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.

Specimens fabrication

Twenty acrylic resin heat –cure samples were used (PROCRYLA,PD) to construct the control group specimens utilising 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 minute 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 manufactures recommended curing procedure.

Mechanical and physical test

Before either test was performed, all samples were kept in 37 degrees Celsius distilled water for 48 hours [12].

A.Impact strength test

The impact strength testing was performed using Charpy impact testing equipment. When calculating the Charpy-impacted strength of specimens without notches, the following formula is used

Impact strength= $\frac{\mathbf{E}}{\mathbf{b.d}} \times \mathbf{10}^{3}$ (ISO No. 179, 2000) where:

E :is the amount of energy that was absorbed by the fracture in joules.

B: the width of the sample in millimeters .

D: represents measurement of the sample's thickness in millimeters.

In this case, the specimen was held horizontally and struck with free-swinging pendulum with impact energy reading on the scale of 5 joules.

B . surface hardness test

In Figure (5) , we see the results of tests run on a durometer hardness tester (model TH 210, China) (shore D hardness).

Typically, the indenter would be pressed down quickly and firmly while the highest reading was recorded. for each specimen , three measurement were taken at various location ,and the average of those reading had recorded.

Statistical Analysis

Microsoft Excel 2010 was used to create the study 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 .

Results

Impact strength test

Table (1) displays the impact strength descriptive statistical data , In contrast to the placebo group, Significant differences were seen between the mean values of the experimental groups at the 1% and 1.5% concentrations of tantalum oxide. Table 2 displays the results of an analysis of variance (ANOVA) test showing a statistically significant difference ($p< 0.05$) between the control and treatment groups .

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Table(1): Descriptive statistics of Impact strength test (KJ/m^2)

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	12.6100	0.48302	0.15275	11.88	13.35
1%	10	13.8080	o.70103	0.22168	12.75	14.73
1.5%	10	14.4110	0.84898	0.26847	12.80	15.85
Total	30	13.6097	1.01400	0.18513	11.88	15.85

Table (2): One-way ANOVA of impact strength test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.808	2	8.404	17.442	0
Within Groups	13.010	27	0.482		
Total	29.818	29			

Hardness test

Table (3) displays the hardness test descriptive statistical data . In contrast to the placebo group, Significant differences were seen between the mean values of the experimental groups at the 1% and 1.5% concentrations of tantalum oxide. . Table 4 displays the results of an analysis of variance (ANOVA) test showing a statistically significant difference ($p< 0.05$) between the control and treatment groups.

Table (3): Descriptive statistics of surface hardness test in (N/mm^2)

	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Control	10	83.6800	0.87407	0.27641	82.30	85.20
1%	10	86.1900	0.88876	0.28105	84.50	87.40
1.5%	10	85.6000	1.71010	0.54078	82.80	87.90
Total	30	85.1567	1.60553	0.29313	82.30	87.90

Table (4): One-way ANOVA of Vickers hardness test

	Sum of Squares	df	Mean Square	F	Sig.
Between Group	34.449	2	17.224	11.538	0
Within Groups	40.305	27	1.493		
Total	74.754	29			

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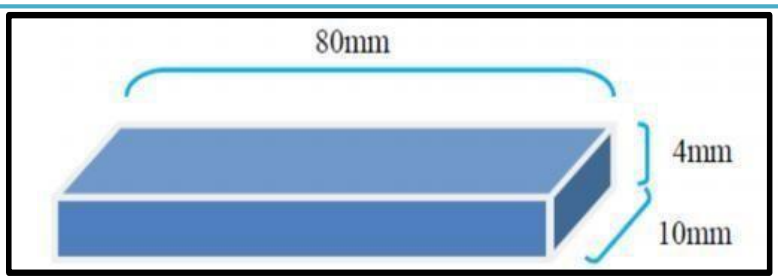

Figure (1) : Impact strength test specimen dimensions

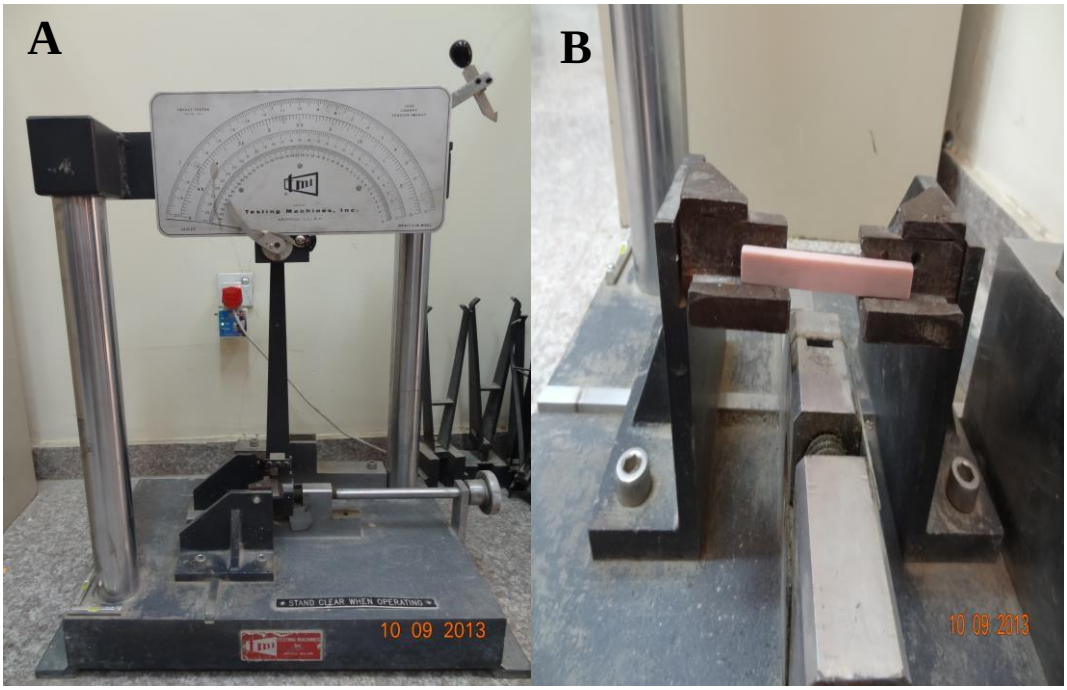

Figure (2):A. Charpy impact testing instrument, B. Impact strength specimen during testing

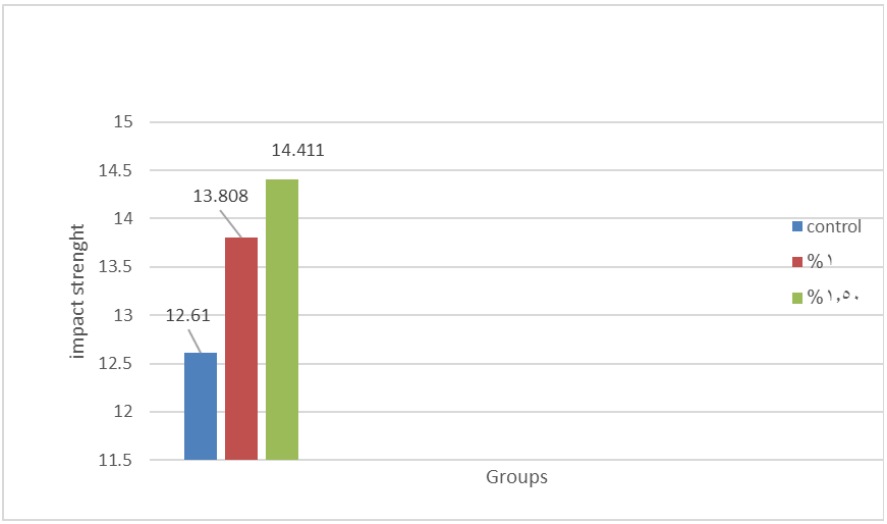

Figure (3): Bar chart of impact strength test showing the mean values and standard deviation

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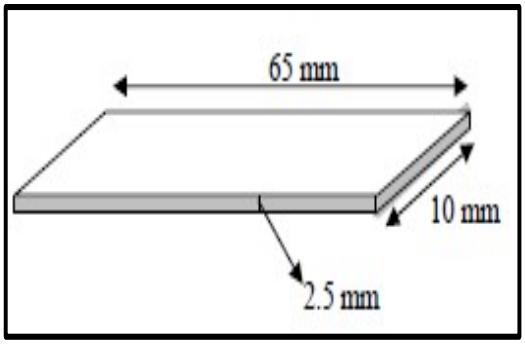

Figure (4): Surface hardness test specimen dimensions

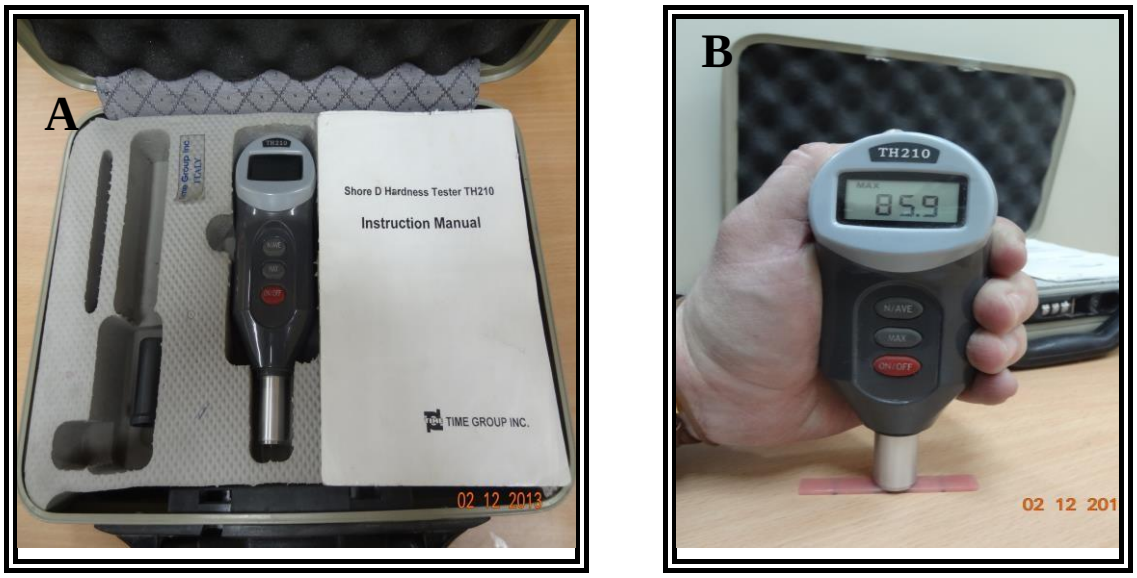

Figure (5):A. Durometer hardness tester-type (Shore D), B. Surface hardness specimen during testing

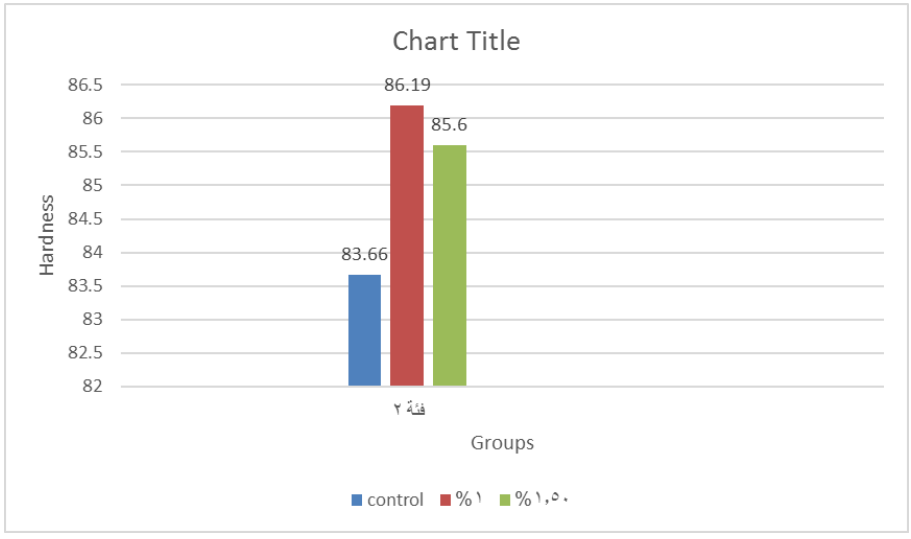

Figure (6): Bar chart of Vickers hardness test showing the mean values and standard deviation

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Discussion

Impact strength

The impact

Strength test" is designed to test the resistance of a material to the sudden application of a load". A standard notched bar is subjected to an impulse load provided by a heavy pendulum. The pendulum is released from a known height, and then strikes and breaks the sample, which is placed across parallel supports. Some of the energy of the pendulum is used up in breaking the sample. From a knowledge of the initial and final height of the pendulum, after it has fractured the sample, the difference in energy can be calculated. This difference is a measure of the amount of energy that was absorbed by the sample, causing it to fracture. The degree of resistance of a polymeric material to impact loading may be of concern in some applications [13].

Impact strength

The energy needed to cause a material to break under an impact force is known as impact strength [14].

According to the results of the research revealed the highest impact strength value for 1.5%wt group as compared with 1%wt. and control group.

Nano fillers may provide a mechanical restriction that limits the mobility and deformation of the matrix [15].

Furthermore, nanoparticles that form Van der Waals bonds between chains and particles increase the constraint between particles/polymer chains and polymer chains themselves, causing chains to carry additional forces [16].

However, since the particle sizes of Ta2O5 Nano powder are very small used in this study, the filler particle size, filler particle concentration, and filler particle dispersion in a polymer matrix, as well As a result of the strong adhesion at the interface, the mechanical properties of particulate filled polymer composites are significantly improved. Filling the voids between polymer particles with Ta2O5 Nano particles creates a heterogeneous blend without disrupting the chain's individual segments. Ultrasonication of Nano particles may also help in proper nanoparticles' dispersion throughout the polymer however the low percentage of nano filler that was added in this study might have helped in well embedding in polymer matrix and this positively affected impact strength [17].

This result is in agreement with Alwan and Alamear (2015) who added 3% wt Titanium oxide nano filler to heat cure PMMA [18] . But disagree with Kamil and Al-Judy when silicon carbide was added to acrylic resin. The dissimilarity could be because of the different filler type [19].

Surface hardness

Hardness represents a material's resistance to scratching, penetration, marring, and so on" [20].

Types of testing techniques have been used to measure the surface hardness of material including (Knoop, Brinell, Rockwell, bacrol, and Vickers), and the selection of each one of these methods will be affected by material type and hardness range [21].

Hardness is the property of a material that indicates how well it resists plastic deformation when pressed upon. A material's scratch- and wear-resistance is quantified by

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this property .The polymer reinforced with Ta2O5 showed higher surface hardness because with the addition of Ta2O5 nanoparticles, the distance between the particles inside the matrix will be decreased . The bonding strength between the particles increases as the inter particle distance decreases, resulting in surface accumulation of hard material particles Ta2o5in the acrylic matrix spaces, resulting in better hardness behavior [22].

Accumulation of the hard material Ta2O5 nano particle in the polymer matrix may be responsible for the enhanced hardness, along with the uniform distribution of nano filler throughout the resin matrix. The 1.5% wt nano Ta2O5 showed more increase in hardness than 1% wt due to more accumulation of nano filler into the resin matrix [23].

The findings agreed with those of Elshereksi (Elshereksi et al, 2016) that add Barium Titanate to denture Base resin[24] and Yang[25], but disagree with the result obtained by Abdul Ameer, 2006 [26] who found that there was a decrease in surface hardness when titanium powder was added to acrylic resin. This might be because the particles used in the experiment were of different sizes.

Conclusions

It was concluded from this study that fracture of the denture is one of the most common problem ,but it reduced when adding this material .

Recommendations

On the basis of this study ,this work can be extended to include:

1-Studying the effect of adding Ta2o5 nanofillers on other properties of acrylic resin such as dimensional stability ,water solubility, water sorption, and color stability

2- studying the effect of adding Ta2o5 nanofillers with cold cure acrylic

3 -studying the impact of adding Ta2o5 nanofillers to high impact acrylic resin

Source of funding: The current study was funded by our charges with no any other funding sources elsewhere.

Ethical clearance: Ethical approval was obtained from the College of Medicine / University of Diyala ethical committee for this study.

Conflict of interest: Nil

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تأثير إضافة مادة التنتلم اوكسايد (مسحوق نانوي Ta2O5) على مادة راتنج الأكريليك على خاصية قوة التأثير وصلابة السطح

سجاد يعقوب يوسف [1] , زينب صالح عبد الله [2]

الملخص

خلفية الدراسة: في البحث الحالي تم تقييم بعض خواص راتنج الأكريليك المعالج بالحرارة بعد إضافة تراكيز مختلفة من تنتلم اوكسايد(Ta2o5) مسحوق نانوي على خاصية قوة التاثير وصلابة السطح.

اهداف الدراسة: للتحقق من آثار إضافة المسحوق النانوي تنتلم اوكسايد على بعض خواص قاعدة طقم الأسنان المعالجة بالحرارة مثل قوة التاثير وصلابة السطح.

المرضى والطرائق: في هذه الدراسة تم عمل ستين عينة (60), عشرين عينة (20) عملت بدون إضافة (أساسية),و(40) عينة عملت مع إضافة مادة التنتلم اوكسايد(1%) و(1.5%)

النتائج: اظهرت نتائج هذه الدراسة زيادة معنوية عالية بنسبة 1,5% بالوزن Ta2o5 في قوة التأثير وصلابة السطح.

الاستنتاجات: يعتبر كسر الأسنان عند المرضى المسنين هو المشكلة الرئيسية ، بينما عند إضافة هذه المادة لوحظ انخفاض في معدل الكسر عند مقارنتها بأطقم الأسنان دون إضافة هذه المادة.

الكلمات المفتاحية: أكريليك قاعدة طقم الاسنان الراتنجية ,بولي مثل ميثااكريليت , تنتلم اوكسايد

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