Al-Rafidain Dental Journal

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The Influence of Titanium Oxide Nanoparticles on Flexural Strength of Poly Methyl Methacrylate Denture Base Material

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Article information

Received: 10 September 2022
Accepted: 5 October 2022
Available online: 10 April 2024

Keywords
PMMA
TiO_2 nanoparticles
Thermal conductivity

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Abstract

Aims: To determine the influence of titanium oxide nanoparticles at two different concentrations (0.5% and 1.0%) on, the thermal conductivity of heat-cured denture base resin. **Materials and Methods:** The specimens, were constructed from PMMA with TiO2 nanoparticles with different concentrations (0.5 and 1%). The specimens were produced using "heat-cured PMMA" and TiO2 nanoparticles, the resulting nanocomposite will depend on the dispersion of the nanoparticles within the matrix, which is directly related to the added amount. The required percentages were weighed and thoroughly mixed with acrylic powder. TiO2 nanoparticles were mixed with the acrylic powder for up to 20 min in an amalgamator to obtain a homogenous mix. Also mortar, and pestle, were used, to attain a uniform mixture and homogenous distribution of TiO2 nanoparticles. The mixture is then combined with the PMMA monomer and stirred before being packed with curing to produce the final specimen, which had been stored in an incubator for two days before testing. Lee's Disc method is used for thermal conductivity tests by apparatus (Griffin and George/England). The specimen for this test was prepared in a cylinder –shape with a thickness of about 3 mm and a diameter is about 40 mm. **Results:** According to the study's findings, there was a statistically significant difference between the groups in terms of thermal conductivity. **Conclusions:** According to the experimental results of PMMA denture base materials, prepared in this research can be concluded the following sentences: The addition of TiO_2 nanoparticles has a remarkable effect on the thermal conductivity of PMMA denture base material with a small concentration of TiO2 nanoparticles. The thermal conductivity of PMMA was increased with the decreasing volume fraction of TiO_2 nanoparticles.

تأثير أضافة جسميات تيتانيوم اوكسيد النانوية على مادة بولى ميثايل ميثاكريليت مادة قاعدة طقم الاسنان

الملخص

الأهداف: تحديد تأثير جزيئات أكسيد التيتانيوم النانوية بتركيزين مختلفين (0.5% و1.0%) على التوصيل الحراري.من راتينج قاعدة طقم الأسنان المعالج بالحرارة. **المواد وطرائق العمل:** تم تصنيع العينات من مادة PMMA مع جزيئات TiO2 النانوية بتراكيز مختلفة (0.5 و 1%)، تم إنتاج العينات باستخدام "PMMA المعالج بالحرارة" والجسيمات النانويةTiO2 ، وسيعتمد المركب النانوي الناتج على تشتت الجسيمات النانوية داخل المصفوفة، والذي يرتبط مباشرة بالكمية المضافة. تم وزن النسب المطلوبة وخلطها جيدًا مع مسحوق الأكريليك. تم خلط جسيمات TiO2 النانوية مع مسحوق الأكريليك لمدة تصل إلى 20 دقيقة في ملغم للحصول على مزيج متجانس. كما تم استخدام الملاط والمدقة للحصول على خليط موحد وتوزيع متجانس لجسيمات ثاني أكسيد التيتانيوم النانوية. يتم بعد ذلك دمج الخليط مع مونومر PMMA وتحريكه قبل تعبئته بالمعالجة لإنتاج العينة النهائية، التي تم تخزينها في حاضنة لمدة يومين قبل الاختبار. استخدام طريقة قرص لي لاختبار التوصيل الحراري بواسطة جهاز (جريفين وجورج/إنجلترا). تم تحضير العينة لهذا الاختبار على شكل اسطوانة سماكتها حوالي 3 مم وقطرها حوالي 40 مم .**النتائج:** وفقا لنتائج الدراسة، كان هناك فرق ذو دلالة إحصائية بين المجموعتين من حيث التوصيل الحراري. **الاستنتاجات:** وفقا لهذا البحث، فإن إضافة "جسيمات Tio2 النانوية إلى مادة PMMA المعالجة بالحرارة" تزيد التوصيل الحراري للمركب النانوي المتولد.

DOI: 10.33899/RDENJ.2024.135826.1174,

INTRODUCTION

Thermal management applications are limited because thermal conductivity in most polymers is low, so it is called a thermal insulator. The solution for this problem is through combining nanoparticles or filler into the matrix of polymer, this will lead greatly to the development of a thermally conductive composite-polymer matrix.

This research discusses the effect of adding TiO2 nanoparticles with two concentrations (0.5, 1 %) to heat cure poly methyl methacrylate and study the thermal conductivity of composite material. A thermal conductivity test was performed on the specimens. The results of this study revealed that values of thermal conductivity were increased with decreasing the volume fraction of Titanium Oxide (TiO_2) nanoparticles.

Polymethylmethacrylate (PMMA) is the most commonly used material for the construction of denture bases because of its advantages like inexpensive, easy to treat, aesthetic properties, and stability in the oral cavity [(1)].

The most widely material used in dentistry applications is acrylic resin and it is accepted among all denture base materials, and it was evaluated that it represents (95%) of the polymer in prosthodontics applications. On the other hand, it has poor questionable mechanical properties [(2)].

The use of poly methyl methacrylate (acrylic resin) appliances is considered a major problem for some dentists and patients. PMMA materials need enhancement in their structure and properties, therefore this was accomplished by combining two or more materials to get more advanced materials and this is a reason why composite materials were invented [(3)].

New chemical and physical properties arise when the size of the material becomes smaller, down to the nanometer scale. In polymer Fillers are used for a variety of reasons, improved processing, cost reduction, optical effect, density control, thermal conductivity, electrical properties, control of thermal expansion, magnetic properties, and hardness [(4)].

Polymer-inorganic oxide nanoparticle composite materials have attracted considerable attention in the field of material science because they show enhanced properties of the material when compared to pure polymers.

The thermo mechanical, electrical, and optical properties of the polymer can be altered because presence of inorganic oxide nanoparticle fillers in the polymer [(5)].

In recent years, composite materials made of polymers and nanoparticles such as inorganic, metal, semiconductor, and magnetic nanomaterial have attracted great attention because of the stabilizing effects of the polymer matrix on the nanoparticles and the relative easiness and flexibility of engineering [(6)].

Titanium dioxide (TiO_2) nanoparticles also known as titanium (IV) oxide or

Titania, is the naturally occurring oxide of titanium. When used as a pigment, it is called titanium white. It is noteworthy for its wide range of applications, from paint to sunscreen to food coloring. Titanium dioxide is found naturally as the mineral anatase, rutile, and brookite. Anatase, rutile, and brookite all contain six coordinates titanium [(7)].

Several nanoparticles such as TiO_2, SiO_2, and ZnO, have [(8)] been incorporated in PMMA to improve mechanical behaviour. Among these nanoparticles, TiO_2 has recently gained prominence because of its noticeable catalytic effect, high stability, availability, white color, and efficiency [(9)].

Also, TiO_2 is non-toxic and chemically inert and has corrosion resistance as well as antibacterial activity and high hardness, they have shown that even low concentrations of TiO_2 nanoparticles can induce new physiochemical, electrical, and optical properties, resulting in an improved new class of nanocomposite materials [(10)].

Polymers possess a relatively inferior thermal conductivity. The thermal highly thermally conductive additives can improve the conductivity of polymer-based material. The existing theories for thermal conductivity like Phonon hopping and minimum thermal conductivity could not explain thermal transport in polymers [(11)].

The results showed that the addition very small concentration of TiO_2 significantly improved the microhardness and thermal conductivity [(12)].

MATERIALS AND METHODS

Thermal conductivity is a phenomenon of heat transfer that occurs to another due to the irritation of particles accompanied by a change in temperature. Thermal conductivity is a measure of the material to conduct heat. Conduction depends on whether the solid is a conductor or an insulator and depending on the nature and potential of the conductor, heat is transmitted through the material with free electrons present in the structure [(13)].

The specimen for this test was prepared in a cylinder –shape with a thickness of about 3 mm and a diameter of about 40 mm, as demonstrated in Figure (1)

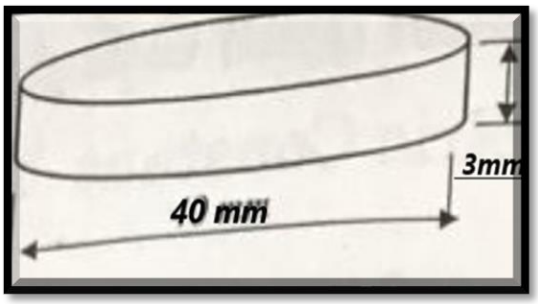

Figure (1): Thermal Conductivity Test Specimen Dimension

Lee's Disc method was used for thermal conductivity tests by apparatus (Griffin and George/England), Figure (2).

Figure (2): Thermal Conductivity Test Apparatus (Lee's Disc Method)

RESULTS

The thermal conductivity of PMMA-TiO_2 nanocomposite in comparison among various concentrations is shown in Figure (3). This figure demonstrated the mean ± SD values for thermal conductivity of PMMA-TiO_2 Nano composite were compared, (0.5%TiO_2, 1% TiO2) with each other and with the control group.

The One-Way Analysis of Variance (ANOVA) as shown in Table (1) shows significant differences among (0.5% TiO_2, 1.0% TiO_2) with Control groups.

Table (1) ANOVA Table for comparing thermal conductivity Between TiO_2 Groups

ANOVA

	Sum of Squares	Df	Mean Square	F	P-value
Between Groups	0.022	2	0.011	81.025	.000
Within Groups	0.004	27	0.000		
Total	0.025	29			

Duncan's Multiple Range Test revealed a significant difference between (0.5%and 1%) TiO2 and control groups. There was a significant difference between the (0.5% and 1%) TiO2 groups, with (the 0.5%) TiO2 group being greater than the other (1.0% TiO_2 and Control) groups, and that 1% TiO_2 was significantly less than the Control group, Figure (3).

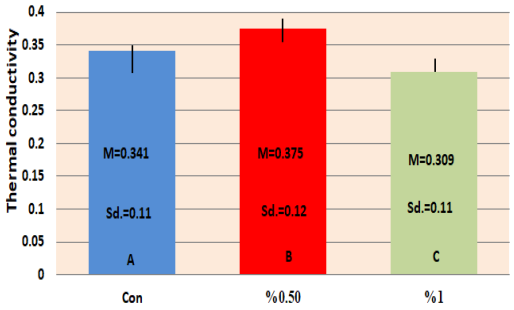

Figure (3): Descriptive statistic and Duncan's multiple range test of thermal conductivity for comparing among TiO2 groups.

DISCUSSION

The thermal property of denture base material would affect patient acceptance of denture prosthesis by altering the sensory experience of drink and food. The capability to feel the temporary temperature change at the palate region, these thermal features play an important role in the gustatory response [(14)].

Under steady-state temperature, thermal conductivity measurement is taken.

The thermal conductivity of polymer materials was low; therefore, the addition of thermally conductive filler enhanced the thermal conductivity of the polymer [(15)].

The results of this study indicate a significant increase in the thermal conductivity of PMMA modified with 0.5% TiO_2 nanoparticles when compared with the control group. But thermal conductivity decreases with 1%TiO_2 nanoparticles [(16)].

Since there is just a small amount of filler in the sample, the system in this work is referred to as a "dispersed system," and

the polymer matrix nearly entirely accounts for heat transmission at low filler contents due to energy transfer between monomers through chemical bonds (primary & secondary). The cooperative motion of monomers and the phenomenon of phonon scattering restrict the range of transfer energies and are grounded in solid-state theory [17].

In accordance with this theory, the change may result in decreased molecular mobility at significant distances from the filler surface. The intermolecular vibrations will be impacted by the decreased molecular mobility in the boundary layers. This led to an increase in heat conductivity. Additionally, many sorts of mechanisms, particularly radiation, contribute to the transport of heat [18].

The interparticle spaces would be smaller because of the very small size nanofiller, so this led to forming paths or bridges that conducted heat and significantly improved thermal conductivity when compared with the control group. The particle size in the composite affects the distances between the particles which enhances the thermal conductivity of the composite in addition to their effect on the mechanical properties of the composite [19].

The thermal conductivity of the polymer was influenced via the size of the filler, shape, volume fraction, and arrangement in the matrix of the polymer [20].

It can be noticed that the results of this study agreed with [22]. who explained that thermal conductivity values of PMMA-TiO_2 specimens decrease with increasing volume fraction of TiO_2 nanoparticles, also the presence of these particles leads to diminishing spaces and voids inside the PMMA matrix which finally leads to increased thermal conductivity values of the composite specimens. [18] reported a positive effect of TiO_2 nanoparticle addition on the temperature of PMMA.

The increase in decomposition temperature for PMMA –TiO2 nanoparticles composite suggests an improved thermal stability. This may be explained by reduced intercrystalline distance, interaction and bond formation between polymer chains and nanoparticles, or absorption of some energy by titanium particles, which increases thermal stability. The thermal stability of TiO_2 nanoparticles added to PMMA inhibits the degradation of the resin and improves the thermal stability of the composite material [22].

The decrease in thermal stability with a higher amount of *N*ano filler may be attributed to the agglomeration of filler particles rather than forming a filler-matrix interaction.

This agglomeration reduces the effect of heat retardation which is associated with TiO_2 nanoparticles. TiO_2 nanoparticle's crystalline phase has free electrons that can be associated with surface reactions. The oxygen that diffused in the Nanocomposite specimen was absorbed on the surface of TiO_2 nanoparticles. Hence, the diffused oxygen amount in the PMMA-matrix was

lower than in pure PMMA which led to slower thermos oxidative degradation of the PMMA-matrix [23].

CONCLUSIONS

According to this study, adding "Tio2 nanoparticles to heat-cured PMMA" increased the thermal conductivity, of the generated nanocomposite. Thermal management applications are limited because thermal conductivity in most polymers is low, so it is called a thermal insulator. The solution for this problem is through combining nanoparticles or filler into the matrix of polymer, this will lead greatly to the development of a thermally conductive composite-polymer matrix. This research discusses the effect of adding TiO2 nanoparticles with two concentrations (0.5, 1 %) to heat cure poly methyl methacrylate and study the thermal conductivity of composite material. A thermal conductivity test was performed on the specimens. The results of this study revealed that values of thermal conductivity were increased with decreasing the volume fraction of Titanium Oxide (TiO_2) nanoparticles.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript.

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