Effects of Nano silver particles on mechanical properties of polymeric dental filling

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Abstract:

Polymeric dental filling (light-cured dental filling) have many problems like polymerization shrinkage and weakness in mechanical properties. Recently, scientists found that nanoparticles are good solutions for many problems in dentistry. Four nanoparticles were prepared ZnO, silver, ZrO2, and TiO2 by sol-gel, laser ablation, chemical, and sol-gel methods. These nanoparticles were then added to light-cured dental filling as fillers. The polymeric dental filling containing the nanoparticles prepared were then examined by X-ray diffraction, depth of cure, compression strength, hardness (lower and upper surfaces), degree of cure, relation between depth of cure and degree of cure, diameter of samples, and polymerization shrinkage. The results showed that polymeric dental filling containing silver nanoparticles had the maximum values of compression strength and hardness with improved mechanical strength with no polymerization shrinkage of the dental filling.

Key words: laser, nanoparticles, light-cured, polymer, and dental filling.

تأثير دقائق الفضة النانوية على الصفات الميكانيكية لحشوة الأسنان البوليمرية

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***فرع العلوم المختبرية السريرية / كلية الصيدلة / الجامعة المستنصرية**

الخلاصة:

حشوة الأسنان البوليميرية (حشوة الأسنان المقساة ضوئيا) لها بعض المشاكل مثل انكماش البلمرة وضعف في الخواص الميكانيكية. في الآونة الأخيرة، وجد العلماء أن الجسيمات النانوية لديها حلول جيدة لكثير من المشاكل في طب الأسنان. فتم إعداد أربع مواد نانوية هي: أوكسيد الزنك والفضة، وثاني أوكسيد الزركونيوم، وثاني أوكسيد التيتانيوم بواسطة الطرق التالية: محلول-غروي، واجتثاث الليزر، والطريقة الكيميائية، وطريقة محلول- غروي. ثم أضيفت هذه الجسيمات النانوية إلى حشوة الأسنان الضوئية كمالىء. ثم تم فحص حشوة الأسنان البوليمرية التي تم تحضيرها والتي تحتوي على الجسيمات النانوية بواسطة: حيود الأشعة السينية وعمق التصليد ومتانة الانضغاط والصلابة (الأسطح السفلية والعلوية) ودرجة التصليد والعلاقة بين عمق التصليد ودرجة التصليد وقطر العينات، وانكماش البلمرة. وأظهرت النتائج أن حشوة الأسنان البوليمرية التي تحتوي على جسيمات الفضة النانوية لديها أقصى القيم من حيث متانة الانضغاط والصلابة وحسنت القوة الميكانيكية وليس فيها انكماش بلمرة لحشوة الأسنان.

الكلمات المفتاحية: ليزر والمواد النانوية والمقساة ضوئيا والبوليمر وحشوة الأسنان.

Introduction

Using resin composite in treating teeth began when Joseph Redenbacher discovered acrylic acid and used acrylic resin as a dental restoration filling [1]. Afterwards, poly methyl methacrylate was used as a resin denture in 1930 [1].

In 1951, another type of dental filling, which was known as resin-based composite, was discovered which was composed of a polymer plus ceramic but suffered from problems like polymerization shrinkage (reducing size of dental filling after polymerization process) and weakness in mechanical properties,

and eventually the fall of polymeric dental filling [2]. For this reason, some of inorganic materials were then added as fillers to this resin composite to solve these problem [3].
After advent of nanotechnology, researchers entered the new science in dental restorative materials where they introduced nanoparticles as filler for dental restorative filling [4].
Inserting nanotechnology in dentistry has great perspective hopes for the dentist and patient.

Constituents of polymeric dental filling

Polymeric dental filling (resin-based composite) has three components:
1.Organic phase like the monomer bisphenol –A- glycidyl methacrylate (BIS-GMA).
2.Inorganic phase which is an inorganic filler like aluminum, silicate or glass.
3.Bonding agent that bond the organic phase to the inorganic filler.
Polymeric dental filling, for this reason, is called a composite because it includes three different materials.

Polymerization process:

The organic phase, the monomer (BIS-GMA), is in fluid state, but when it is cured by light, the monomers convert to polymer in its solid state. Cure process is transformation of fluid material to solid material.
The types of lights used in curing process are: halogen, laser, LED, and ultraviolet. When any one of these types of light fall on organic phase or polymeric dental filling, the monomers link together to form polymer and convert to solid state.
Photopolymerization process (curing) is transformation of monomers to polymer using light. The more monomers convert to polymer, the higher the polymerization degree i.e., polymerization enhances hardening of the material.

Aim of this work

The aim of this work is to improve polymeric dental filling by the use of nanoparticles.

Materials and Methods:

The base material that was used in this work is the polymeric dental filling "COMPOSAN LCM" which has three phases mentioned above.
Four nanomaterials were prepared, as explained in 2.1, and then added as filler as inorganic phase to the base material (COMPOSAN LCM).

Preparation of the four nanoparticles:

Four nanomaterials were prepared as follows: ZnO nanoparticles (ZnONPs) by sol-gel method [6], silver nanoparticles by laser ablation [7], ZrO2 nanoparticles (ZrO2NPs) by chemical method [8], and TiO2 nanoparticles by chemical method [9].

Preparing the dental filling samples:

The nanoparticles (inorganic phase) that were prepared in 2.1 were added as fillers to the base material (the organic phase), the dental filling "COMPOSAN LCM".
The new mixture composed of organic phase and inorganic phase is called composite. It is resin-based composite.
This composite with three ratios of the fillers was then put in templates to be cured by light with three periods of exposure 10 seconds, 15 seconds, and 20 seconds except silver filler; which were cured at 10, 20, and 30 seconds.
The light, that was used in this work, is LED. The composite samples, that were done, were characterized by several tests as follows.

Characterizations of the composite samples:

The composite resin samples prepared were examined by depth of cure, compression strength, upper surface hardness, lower surface hardness, degree of cure, relation between degree of cure

and depth of cure, diameter of samples, and polymerization shrinkage tests.

Compressions strength (σ)

To achieve this examination, resin composite mixture samples prepared were put in cylindrical template of 3mm diameter and 6mm thickness and then cured by LED. The samples produced were then tested by " micrometer controlled electronic universal testing machine". All the samples and tests obey the criteria of (ISO 9917).

Upper surface hardness

To do this test, composite samples were put in cylindrical template with 6mm diameter and 2mm height. After the samples had been cured by LED, they were tested by PS 2006 VIDRO MEASURING DEVICE is TH 717 digital micro hardness.

Shrinkage, diameter (D)

To calculate polymerization shrinkage, diameter (D) in mm of samples was calculated. The template that was used to do this test is 6x8mm cylinder. It was assumed that diameter of sample before using is D1. D1 was equal to 6mm for all samples. Diameter of sample after curing is D2.

Polymerization shrinkage (PS)

Polymerization shrinkage (PS) is defined as: It is reduction in size of sample after it is cured. Polymerization shrinkage was measured by the equation (1):

PS ---------- (1)

Where

PS is polymerization shrinkage.

D1 is diameter of sample before curing.

D2 is diameter of sample after curing [14].

Results and discussion:

Compression strength (σ) test:

From the figures (1) to (4), it seems that compression strength (σ) increases with increasing light exposure time; as it increases monomers involved in the organic phase converted to polymers and enhances polymerization degree [10], and it could be seen that when filler load increases, composite compression strength increases [11]; that is because the filler is an inorganic solid material [12].

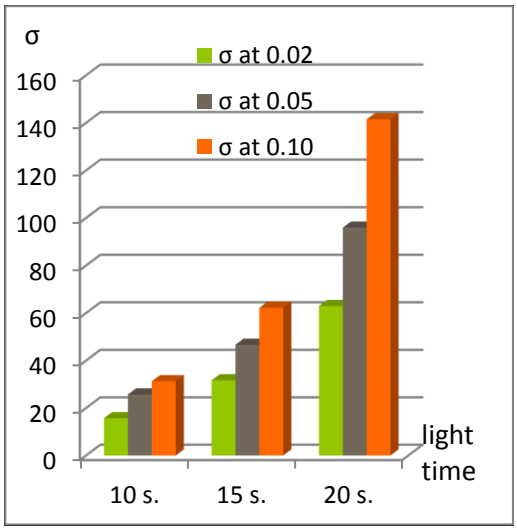

Figure (1): compression strength (σ) in MPa values of ZnO filler-containing resin composite Samples in three exposure times of light at the filler ratios 0.02, 0.05, 0.10 of ZnO.

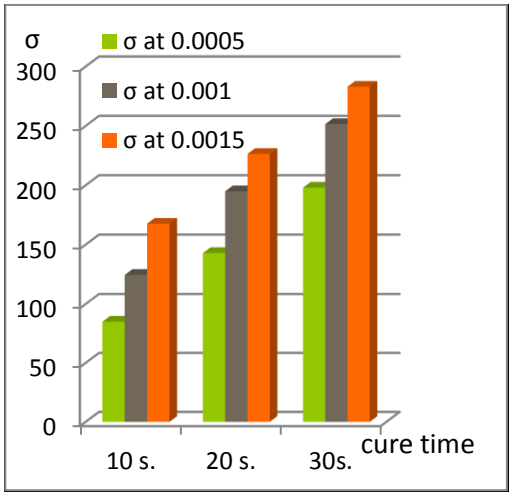

Figure (2): values of compression strength (σ) in MPa of the composite samples containing the ratios 0.0005, 0.001, and 0.0015 of the silver fillers.

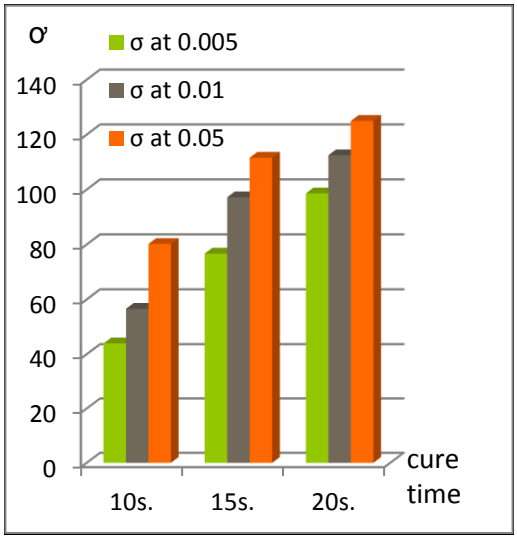

Figure (3): values of compression strength (σ) of the composite samples containing the ratios 0.005, 0.01, and 0.05 of ZrO_2 filler against time of light.

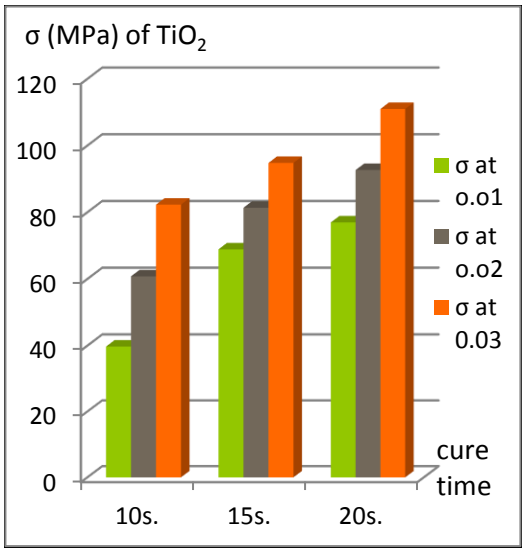

Figure (4): values of compression strength of TiO_2 filler at the ratios 0.01, 0.02, and 0.03.

Results of upper surface hardness test:

From the figures (5) to (8), it can be concluded that upper surface hardness increases with increasing filler ratio. The reason of that is the solidity of the fillers [11]. Besides that, the fillers are nanomaterials, and seldom does nanomaterial include inter distances between particles; this increases solidity, and thus upper surface hardness increases with increasing filler ratio [13].

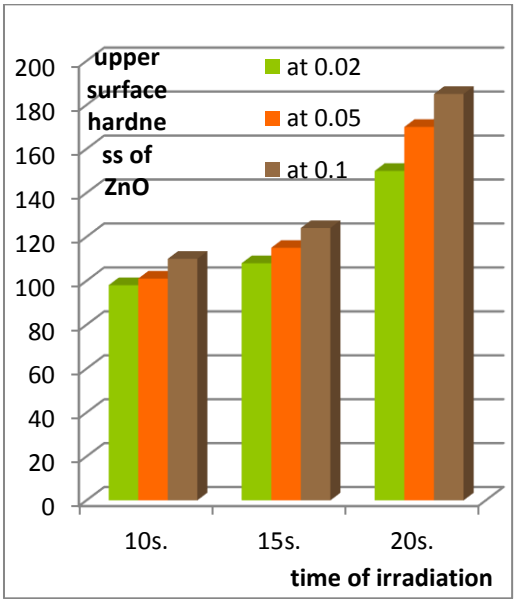

Figure (5): values of upper surface hardness in MPa of ZnO filler-composite samples at the ratios 0.02, 0.05, and 0.01 versus LED exposure time.

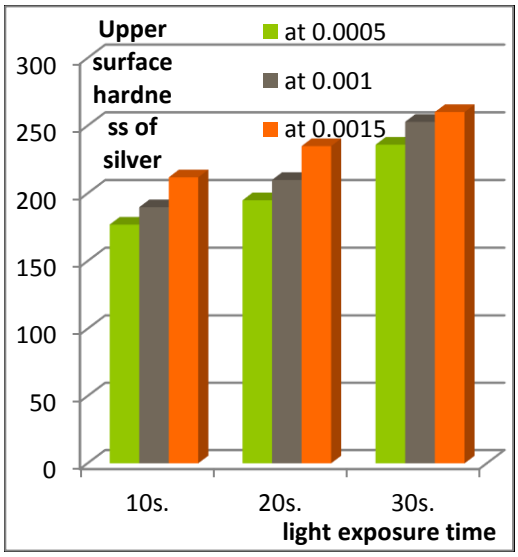

Figure (6): upper surface hardness values of silver filler in its ratios 0.0005, 0.001, and 0.0015 at exposure time 10, 20, and 30 seconds.

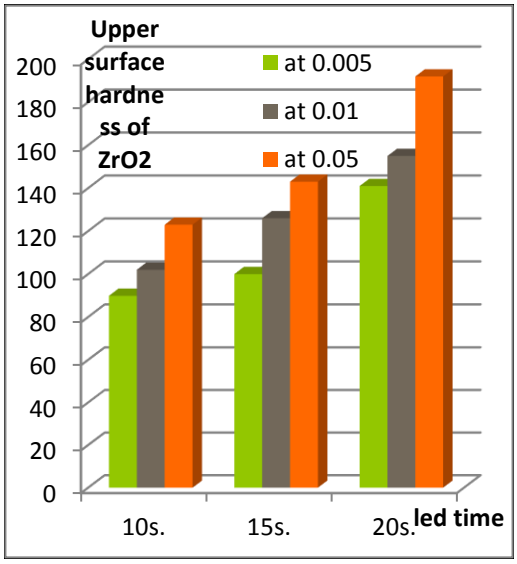

Figure (7): upper surface hardness of ZrO_2 filler at the ratios 0.005, 0.01, and 0.05.

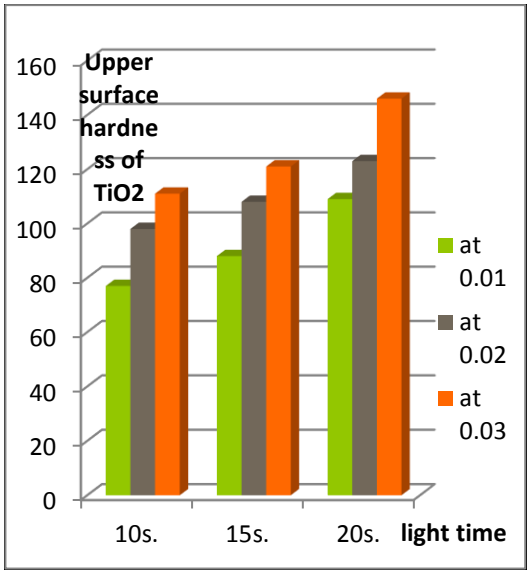

Figure (8): upper surface hardness of TiO_2 filler at the ratios 0.01, 0.02, and 0.03.

Shrinkage diameters (D):

The results of diameter after curing (D_2) are displayed in the figures (9) to (12). From these figures, it could be seen that diameter of the samples increases with increasing light exposure time; the reason is when light time increases, more monomers convert to polymers; thus, polymerization degree enhances. It could also be seen from the figures that increasing filler load increases diameter of the samples, i.e., increasing filler ratio improves polymerization process.

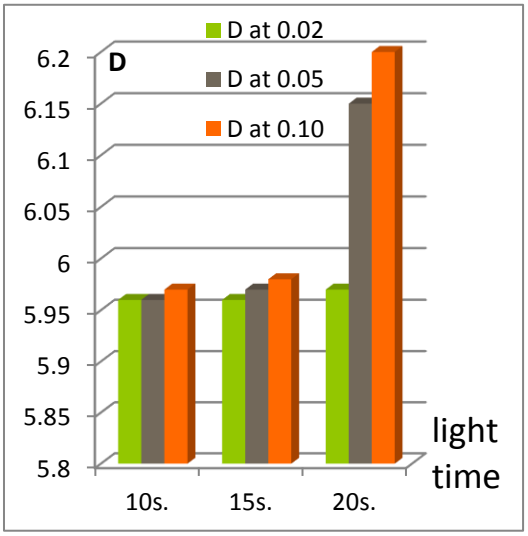

Figure (9): diameter of the samples containing ZnO filler at the ratios 0.02, 0.05, and 0.1 versus LED period time.

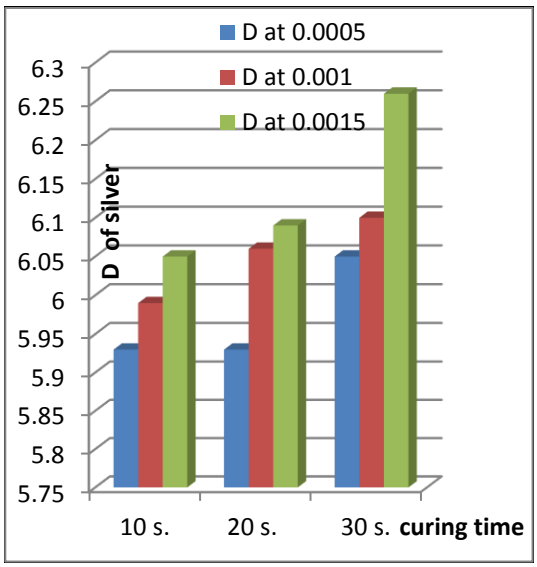

Figure (10): diameter of silver filler–containing resin composite samples at the ratios 0.0005, 0.001, and 0.0015 versus 10s. 20s. and 30s of exposure time.

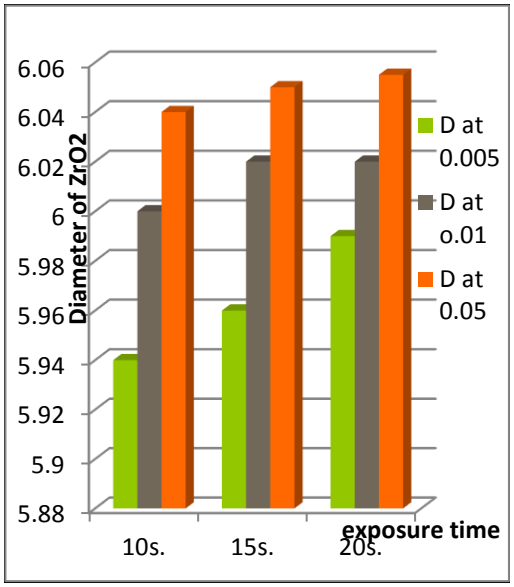

Figure (11): diameter of ZrO_2-containing samples at the ratios 0.005, 0.01, and 0.05 versus LED light.

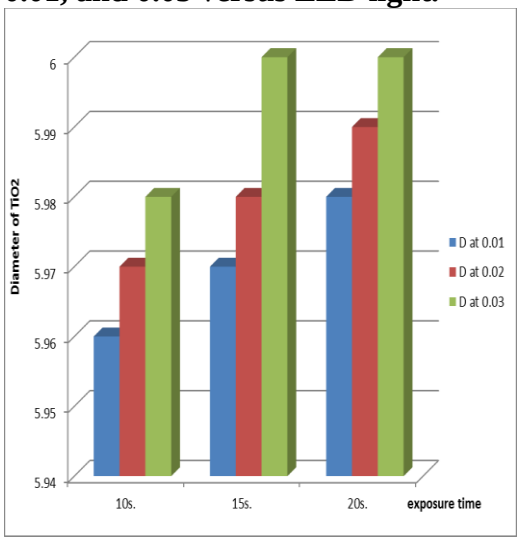

Figure (12): diameter of TiO_2 filler-containing samples at the ratios 0.01, 0.02, and 0.03 versus light time.

Polymerization Shrinkage (PS) test:

From the figures (13) to (16), it could be concluded that increasing light exposure duration reduces polymerization shrinkage because more monomers will convert to polymers; thus, polymerization degree enhances [15].

The minus sign means that sample expand, while the positive sign means sample contract.

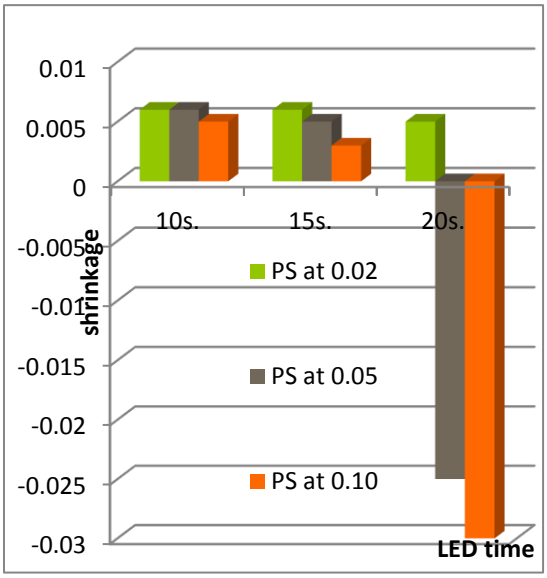

Figure (13): Polymerization shrinkage values of ZnO filler–containing composite resin at ZnO ratios 0.02, 0.05, 0.10.

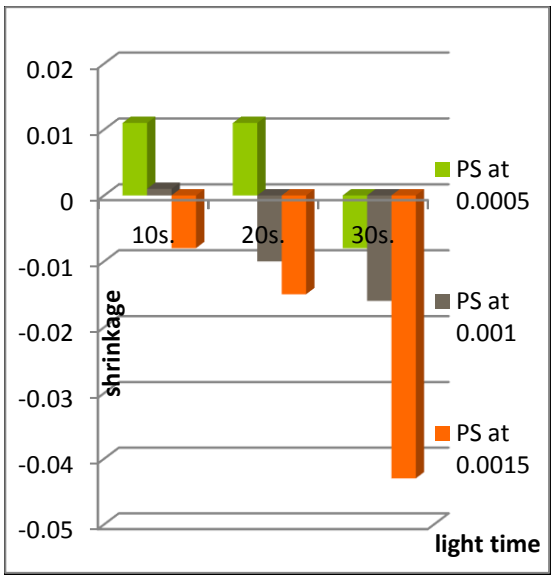

Figure (14): PS of silver filler values at silver ratios 0.0005, 0.001, and 0.0015.

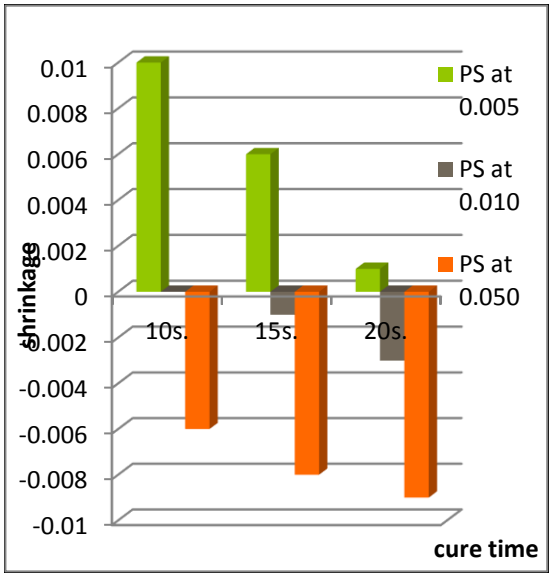

Figure (15): PS values of the filler ZrO_2 at the ratios 0.005, 0.01, and 0.05.

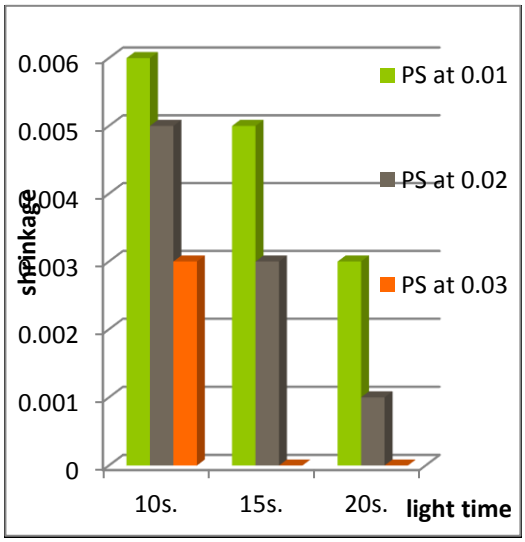

Figure (16): Polymerization shrinkage values of TiO_2 filer at the ratios 0.01, 0.02, and 0.03.

It could also be seen from these figures that increasing filler load reduces polymerization shrinkage; that agrees with [16,11,17] and means that these fillers at these ratios enhance polymerization process thus improve dental restorative filling.

The best ratio for the dental filling to expand with silver filler is at 0.0015.

From the figures above, it can be concluded that there is no polymerization shrinkage with Nano silver filler at most of its ratios; beside that, the mechanical properties are much better than other fillers.

Conclusions:

The most important conclusion in this work is that Nano silver solves polymerization shrinkage problem of polymeric (light-cured) dental filling and cancels it, and polymeric or light-cured dental filling will not fall, in the permission of Allah.

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