Effect of Silver Nanoparticles and silver hydroxyapatite nanoparticles on Color and Fracture Strength of Dental Ceramic.

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Abstract: Aim of the study: investigation of the Effect of Silver Nanoparticles and silver hydroxyapatite nanoparticles on Color and Fracture Strength of Dental ceramic. **Materials and Methods**: Silver nanoparticle and silver hydroxyapatite nanoparticles of 40ug/ml concentration was added to Dental porcelain in a ratio 1:100 and manipulated by conventional method. A total of 30 samples were constructed. They were divided into 3 groups (10 samples each), group I without any modification, group II silver nanoparticles modified porcelain samples and group III silver hydroxyapatite modified porcelain samples. Then each group was subjected to color change test and fracture strength test (5 samples each). Color change was tested using a vita easy shade apparatus while fracture strength was measured using universal testing machine. Results were tabulated and statistically analyzed. **Results:** group II demonstrated higher fracture strength (30.3 ± 0.3 Mpa) than control group (group I) (25.9 ± 0.5Mpa). Whereas, group III showed lower fracture strength values (17.5 ± 1.5 Mpa) in comparison with the control group (25.9 ± 0.5Mpa). There was an increase in the lightness of group III (mean ΔL = 16.1) which created lighter samples than control, whereas there was a decrease in the lightness (mean ΔL = -24.9) in group II which created darker samples than control group. **Conclusions:** The addition of silver nanoparticles have been increased the fracture strength of dental ceramic. 2- The addition of silver hydroxyapatite nanoparticles have been decreased the fracture strength of dental ceramic. 3- Addition of silver nanoparticles and silver hydroxyapatite nanoparticles affected the color of dental ceramic adversely.

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Introduction

Porcelain is used in aesthetic dentistry to realize cosmetic restoration in the oral cavity and to achieve appropriate optical properties. Moreover, the requirements for porcelain are not purely cosmetic; it also needs to be sufficiently strong to withstand masticatory functions and to be durable. However, the dispersion of reinforcement particles which is the most prevalent method to strengthen ceramics may lead to color change of dental ceramic. [1-3]

Veneered ceramic and metal ceramic crowns are widely used in dentistry because of their excellent esthetics and mechanical durability. They are fabricated by fusing porcelain onto a metal or ceramic coping. However, it is sometimes necessary to replace restorations because of fracture or chipping of the veneering porcelain. Unlike metals, porcelain is not malleable or ductile and readily cracks or breaks with virtually no deformation when an excessive force is applied. The brittleness of porcelain renders it susceptible to chipping or fractures under strong occlusal forces, such as occurs with bruxism, sometimes necessitating removal of the restoration. To inhibit the fracture and chipping of the veneering porcelain and to improve the mechanical reliability of restoration, One method to toughen glass or glass ceramics such as porcelain is the addition of ductile metal particles, which has been shown to improve toughness through crack bridging and deflection by the metal particles. [2, 4] **Kon et al**., in (1994) [5] reported that the strength of composite porcelain with particles dispersed in the glass matrix is enhanced by the suppression of cracking through deflection, bowing, and pinning mechanisms. **Tokushi et a**l., in (2012) [6] evaluated the addition of nanoparticles of precious metals of silver and platinum (rather than non-precious metals) to increase the fracture resistance of porcelain. They found that the addition of silver and platinum nanoparticles improved the mechanical properties of porcelain since it increased both the Young's modulus and the fracture toughness of commercial porcelain.

Azam Akhavan et al., in (2013) [7] investigate the effect of incorporating Silver and Hydroxyapatite (HA) nanoparticles on the shear bond strength (SBS) of an orthodontic adhesive. The nanoparticles were added to the primer of Trans bond XT in 1%, 5% and 10% silver concentrations. Each compound (along

with a control) was used for bonding stainless steel brackets to 12 human premolars and the SBS of all samples was measured. Results showed that incorporation of silver/HA nanoparticles containing 5% and 1% silver maintains and increases the SBS of orthodontic adhesives, respectively, whereas increasing the amount of particles to 10% has an undesirable effect when compared to the control group. **Mary Anne et** al., in (2013) [8] incorporated nanoparticles of silver (NAg) and nanoparticles of amorphous calcium phosphate (NACP) into adhesive for the first time to investigate the effects on dentin bond strength and plaque biofilms. They used Scotch bond multi-purpose adhesive as control. NAg was added into primer and adhesive at 0.1% by mass. NACP were mixed into adhesive at 10%, 20%, 30% and 40%. Biofilm metabolic activity, colony-forming units (CFU) and lactic acid were measured. They found that adding NAg and NACP into adhesive did not decrease the bond strength ($p > 0.1$), NACP had little antibacterial effect,

Mitsunori et al., in (2013) [2] investigated the toughening of porcelain through the addition of silver nanoparticles. They used Noritake Super (NS) Porcelain modified with the addition of silver nanoparticles. The concentration of silver in the solution was adjusted to 100, 200, 500, and 1000 ppm (Ag100, Ag200, Ag500, and Ag1000). The results showed that the addition of silver nanoparticles significantly increased the fracture toughness and Vickers hardness of the NS porcelain. However, the addition of Ag500 and Ag1000 nanoparticles led to a color change.

Tokushi F et al., in (2013) [9] clarify the effect of silver nanoparticles on the behavior of subcritical crack growth (SCG) in dental porcelains. SCG in dental porcelains can be characterized by the stress corrosion susceptibility coefficient, *n*. A higher *n* value means a higher resistance to SCG. A Vickers indenter was applied to the porcelain surface, and lengths of median cracks were measured at fixed time intervals over a 24-h period to calculate *n*. The results showed that addition of silver nanoparticles significantly increased the stress corrosion susceptibility coefficient of dental porcelain. **Holloway and Miller**, in (1997) [10] reported that some reinforcing particles are exceptionally opaque, and the compromise between strength and translucency becomes evident when comparing the translucency and the relative strength values of each material. **Holloway and Spear**, in (2008) [11] reported that ceramics with high strength tend to be more opaque and pose a challenge when trying to match natural tooth color, but they can mask discoloration when it is present.

Therefore the aim of this study was to evaluate the effect of silver nanoparticles on color and fracture strength of dental ceramic.

Materials & Methods

1-Preparation of control samples (group I)

A split tephlon disc of 5 mm diameter and 2 mm thickness was used as a mold for the samples used in testing color to standardize the shape and size of the samples. A custom made mold of 2 mm thickness, 25mm length and 5mm width was used for preparing samples used for fracture strength measurement.

The porcelain powder was mixed with porcelain molding liquid to form a past. A moistened brush was used to apply each porcelain layer in small increments until it reached its step level in the mold. The samples were dried by heating slowly in the open entrance of the furnace. This is carried out in order to drive off excess water before it has a chance to form steam, once the compact has been dried. The porcelain samples were fired in a porcelain furnace ,Firing protocol (drying for 5 minutes, rate of temperature increase: 50°C/minute, vacuum value: 730 mmHg, firing initiation temperature: 680°C, firing finishing

temperature: 930°C for 30 minutes then rapid cooling was done in porcelain furnace).

2-Preparation of modified porcelain samples (group II and III).

The Silver nanoparticles powder and silver Hydroxyapatite nanoparticles powder was weighed with an electronic sensitive balance and added to the powder of the dental porcelain in a ratio 1:100. And manipulated as previously explained in control samples.

3-Fracture Strength measurement.

Fracture strength measurement of different porcelain samples, (group I, group II and group III) was performed using compressive load test in a universal testing machine. The porcelain samples length between the cross-heads of the machine was standardized as 25 mm. The full scale load was set with a crosshead speed of 5 mm/min. Statistical analysis was undertaken by one-way analysis of variance (ANOVA, p=0.05).

4-Color Changes test.

A total of fifteen samples of the same shade 2m3 (Vita 3D Master shade guide) of dental porcelain were constructed and all samples, (group I, group II and group III) were 2mm thick to simulate the clinical thickness.

The VITA Easy Shade instrument which provides accurate shade determination for natural dentition and a variety of restorations was used. Vita Easy Shade was calibrated first. Measurement of the shade samples were made in a single tooth mode. Each sample was measured by holding the probe tip at

90 to the surface in the center of the sample, according the manufacturer instruction the measurement was accepted when 2 consecutive, identical reading generated for each tab.

Color measurements were recorded in the 3 color parameters a.b.L. (-a-) Measure the redness, when plus, gray when zero and greenness when minus, (-b-) Measure the yellowish when plus, gray when zero and blueness when minus and (–L-) Measure the lightness, it decreases the chromatic character of the color.

Figure (3) The VITA Easy Shade apparatus**.**

5-Energy Dispersive X- ray analysis (EDAX).

Samples will be characterized by Energy Dispersive X- ray analysis. EDAX: is a widely technique used to analyze the chemical components in a material under scanning electron microscope (SEM). Mapping of the distribution of the different chemical elements constituting the specimen can be obtained. X- ray data is processed to obtain the percentage of each measured element present.

Results

1-Fracture strength test results

Pair-wise comparisons between the groups revealed that group II showed the statistically significantly highest mean fracture strength. Group I showed statistically significantly lower mean value. Group III showed the statistically significantly lowest mean fracture strength.

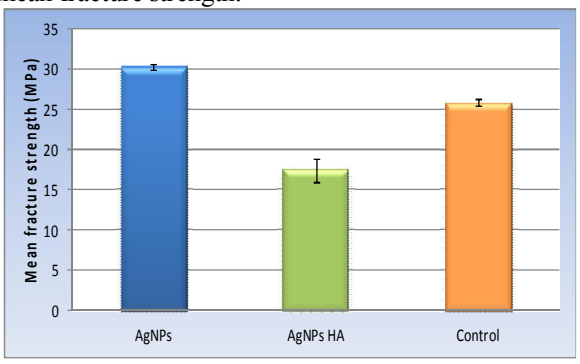

Figure (1): Mean fracture strength value in different groups.

Table (1): Comparison between fracture strength values in different groups.

AgNPs	AgNPs HA	Control	*P*-value
30.3 ± 0.3 [a]	17.5 ± 1.5 [c]	25.9 ± 0.5 [b]	<0.001*

**: Significant at P ≤ 0.05, Different superscripts are statistically significantly different.*

2-Color change test results

Group II showed statistically significantly higher mean (ΔE) than group III (*P*-value = 0.001). As regards (ΔL); group II showed a decrease in mean (ΔL) while group III showed an increase in mean (ΔL). There was a statistically significant difference between the two groups (*P*-value < 0.001). As regards (Δa); group II showed an increase in mean (Δa) while group III showed a decrease in mean (Δa). There was a statistically significant difference between the two groups (*P*-value = 0.001). As regards (Δb); group II showed a decrease in mean (Δb) while group III showed an increase in mean (Δb). There was a statistically significant difference between the two groups (*P*-value < 0.001).

Table (2): Comparison between mean color change (ΔE), (ΔL), (Δb), and (Δa) in group II and III.

	AgNPs	AgNPs HA	P-value
ΔE	29.2 ± 3.2	21.3 ± 0.7	0.001*
ΔL	-24.9 ± 3.9	16.1 ± 0.8	<0.001*
Δa	3.8 ± 1.2	-0.2 ± 0.03	0.001*
Δb	14.2 ± 4.1	-13.9 ± 0.4	<0.001*

**: Significant at P ≤ 0.05*

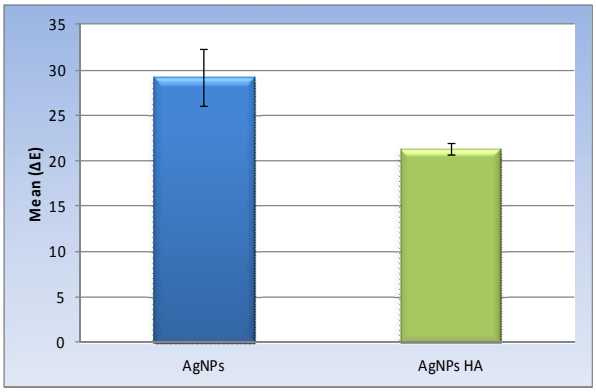

Figure (2): Mean (ΔE) in group II and III.

3-Energy Dispersive X- ray analysis (EDAX) results.

Energy Dispersive X-ray analysis results reveal the homogenous distribution of silver nanoparticles on the surface of modified porcelain samples as showen in figure 3.

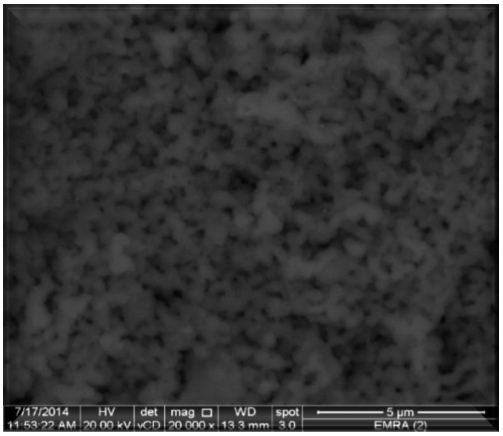

Figure (3): Energy dispersive X ray analysis image of the modified porcelain samples.

Discussion

Porcelain is used in aesthetic dentistry to achieve appropriate optical properties in the oral cavity. Moreover, the requirements for porcelain are not purely cosmetic; it also needs to be sufficiently strong to withstand masticatory functions and to be durable. [2,3] To increase the fracture strength of glass, the addition of metals such as Ni, Al, and W and metal alloys such as FeNiCo , FeCr, and stainless steel has been investigated. These metals and alloys were either in the form of particles [12-16] or chopped fiers. [17, 18] these additions of metal had sizes of the order of micrometers. The two most common mechanisms that have been proposed for toughening of the glass matrix by the addition of particles are bridging of cracks by stretching particles, and crack deflection around the particles [19]. Thus, metal particles are expected to increase the fracture resistance of porcelain in dental applications. However, the metals that have been used are non-precious metals, which are harmful when used in the mouth; furthermore, the materials contained in those metals have mainly been applied for structural applications, rather than dental applications. The addition of silver nanoparticles in the present study is mainly for its antibacterial effect, yet, it is expected to have influence on the fracture strength of the studied porcelain.

Silver nanoparticles modified porcelain samples (group II) demonstrated higher fracture strength (30.3 ± 0.3 Mpa) than the control group (group I) (25.9 ± 0.5Mpa). This Increasing in fracture strength may be due to the higher coefficient of thermal expansion of silver than that of the glass matrix. So tensile stress occurs in the radial direction of the particle and a compressive stress in the tangential direction. Therefore, cracks extending towards the silver particles are inhibited by the compressive stress in the tangential direction, causing crack deflection. Moreover the crack-bridging phenomenon occurs when the ductile metal acts to inhibit the extension of cracks. Generally, the strength of porcelains with particles dispersed in the glass matrix is enhanced by the suppression of cracking through deflection and bridging mechanisms. [2, 5, 6, 9] The results of this study were in accordance with the results obtained by Dlouhy et al. [20] as the inherent ductility of the metallic phase can be utilized to inhibit propagation of a running crack through the nanoparticles; in other words, a crack can be bridged by stretching the nanoparticles.

Whereas, silver hydroxyapatite nanoparticles modified porcelain samples (group III) showed lower fracture strength values (17.5 ± 1.5 Mpa) in comparison with the control group (25.9 ± 0.5Mpa). It could be due to an agglomeration of particles, creating defect points that interfering with the sintering process of dental porcelain lead to decrease in the strength. The same results were reported by other investigators where the addition of hydroxyapatite in higher percentage leads to decrease in strength of dental porcelain [21].

This color change may be due to the silvery grayish color of Ag nanoparticles which is supported by energy dispersive X-ray analysis (EDAX) which reveal the homogenous distribution of silver nanoparticles on the surface of the tested samples (group II and III). Another explanation to color change that Ag spectrum is in far UV spectrum, but in case of adding Ag to SIO_2, the major component of the studied porcelain. The expected reaction is the formation of AgO which is a grayish oxide. While in case of silver hydroxyapatite and due to the calcium and phosphorus oxides that predominate in the porcelain matrix structure. So it is expected to whiten the color or in other words, lighten the final shade of samples in group III. This color change was in dentin porcelain and can be masked by enamel porcelain and we can choose lighter shade to compensate this change in color.

Conclusions

Under the limitations of this study, several conclusions could be detected:

1- The addition of silver nanoparticles have been increased the fracture strength of dental ceramic.

2- addition of silver hydroxyapatite nanoparticles have been decreased the fracture strength of dental ceramic.

3- Addition of silver nanoparticles and silver hydroxyapatite nanoparticles affected the color of dental ceramic adversely.

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