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FIXED PROSTHODONTICS AND DENTAL MATERIALS

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EFFECT OF NANO SILICA INCORPORATION ON COLOUR AND MECHANICAL PROPERTIES OF TWO PROVISIONAL MATERIALS

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ABSTRACT

Aim: The aim of this research was to assess the reinforcing effect of silica nanoparticles on two provisional materials, by measuring the flexural strength and diametral tensile strength, as well as the influence on colour change

Methods: A total of sixty samples of two provisional materials were constructed and classified into two groups (n=30), group 1 (Voco structure 2sc) and group 2 (Charm temp). Each group was classified into two subgroups (n=15) according to modification by silica nanoparticles, subgroup 1 (control) and subgroup II (modified by silica nanoparticles). Each subgroup was classified into three classes according to the type of the test (n=5) Flexural strength, diametral tensile strength tests which were measured by using the universal testing machine, and colour change test was performed by spectrophotometer. Data were collected, tabulated and statically analyzed.

Results: Diametral tensile strength results showed a significant increase in modified samples (11.4±1.7, 14.2±3.7) in comparison to control samples (6.1±1.7, 8.3±2.2) in charm and voco, respectively. Regarding the flexural strength results, there was a non-significant decrease in modified samples (59.4±4.1, 33.5±4.9) in comparison to control samples (62.7±1.2, 42.1±11) in charm and voco, respectively. Colour change results showed a statistically significant increase in (ΔE) value in charm temp (5.1±1.7) in comparison to voco provisional material (2.4±0.8).

Conclusions: The addition of silica nanoparticles to both provisional materials significantly improves the diametral tensile strength, whereas decreases the flexural strength insignificantly. Colour change in voco structure 2sc was within the acceptable clinical range whereas in charm was above this range.

KEYWORDS: Provisional material, silica nanoparticles, colour, flexural strength, diametral tensile strength

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INTRODUCTION

In recent years, nanotechnology has developed several nanoparticles that are commonly employed to enhance the mechanical properties of dental materials.[1] Various nanoparticles have been shown to greatly increase the flexural strength of dental resin matrix; in fact, nanoparticles were more efficient than macroparticles in mechanically reinforcing resin matrix. [2] Silica, among these many nanoparticles, is preferred in dental resins due to its great strength and good cosmetic qualities. [3]

In the dental clinic, temporary restorations are often used to protect prepared teeth while permanent ones are available. These restorations must be esthetic, have excellent mechanical characteristics to endure stresses in the mouth cavity and be physiologically compatible to restore function.[4] Clinicians may utilize a variety of resources for this aim. The two polymers that are most often used for that purpose are bis-acryl and polymethylmethacrylate (PMMA). [5] Even though interim restorations are only used temporarily, there are specific circumstances when they are necessary. These situations include individuals with parafunctional habits, full mouth rehabilitation, and restoration of the vertical dimension of occlusion. Materials with improved mechanical characteristics are necessary for long-term temporary repairs. [6]

Due to this, several efforts have been undertaken to improve the fracture strength of PMMA restorations using metal wires, fibers (glass, aramid, and carbon graphite), different oxides (aluminum, zirconium, titanium, magnesium), and nanodiamonds. While carbon fibers achieve a dark hue that restricts their usage, metal wires have an applicability that is limited by aesthetics and space availability. [7,8] Recently, Topouzi et al. [9] showed a considerable improvement in the mechanical characteristics of a PMMA acrylic resin reinforced with SiO2 nanoparticles. Silica, on the other hand, is a white, opaque powder that can negatively impact the PMMA resin's colour. In general, reinforcement chemicals employed in temporary restoration should strengthen the substance without changing its colour.

PMMA and other polymeric dental materials have been effectively combined with amorphous-crystalline silica nanoparticles. The mechanical and thermal characteristics of these materials have been significantly impacted by several experimental research. Reduced mechanical qualities, however, may be the consequence of adding nanoparticles in an inappropriate kind or dosage. [10] Nano silica natural powder has indeed been chosen as a biocompatible material with good fracture resistance to improve the attributes of PMMA. [11] Recently, there has been an interest in using inorganic nanoparticles to improve polymer performance. Due to its optical and mechanical qualities, silica-polymethylmethacrylate (PMMA) is the nano-composite material that has been studied the most. [12]

According to the literature, compressive strength and diametral tensile strength are positively correlated. Both forms of testing include subjecting specimens to a compressive load that is delivered in a variety of planes, fracture results from internal tensile and complicated shear stresses in the material. Testing for the diametral tensile strength of brittle materials with little to no plastic deformation was created for this purpose. This test involves applying a compressive force to a cylindrical specimen in the diametral plane, which is parallel to the longitudinal axis. [13,14]

There have been attempts to reinforce temporary resins using a variety of components. [15] However, the use of nanoparticles for interim restorative reinforcement is still being researched, and the dental literature is deficient in pertinent information while the available documentation displays a very limited range of data. In order to better understand how silica nanoparticles, reinforce two temporary restorations' flexural strength and diametral tensile strength as well as how they affect colour, this research was proposed.

Hypothesis:

The study's hypothesis proposed that adding silica nanoparticles to provisional material would affect its flexural and diametral tensile strength without changing its colour.

MATERIALS AND METHODS

Ethical consent was not necessary for this work since no human or animal data or tissues were used. Prior to the investigation, a power calculation using information from earlier research was used to establish the number of samples needed in each group.[16] In that research, the mean flexure strength was 64.2 11.28 in the control group and 100.2 18.41 in the modified group. Using G Power 3.1 9.2 software, it was found that a sample size of 5 samples in each group would offer 80% power for an independent Samples T-test at the threshold of 0.05 significance.

A total number of sixty samples of two provisional restorative materials were constructed and classified into two groups n=30 group (I) Charm temp provisional restorative material and group (II)Voco provisional restorative material. Each group was divided into two subgroups (n=15) based on the alteration by silica nanoparticles: subgroup I was the control group (without any modification) and subgroup II was the modified group (samples modified by silica nanoparticles). Then, each subgroup was divided into three classes based on the type of the test (n=5). Tests for flexural strength, diametral tensile strength, and colour change test were performed.

The temporary materials we used in our study were 1- Charm Temp acrylic resin (DentKist, Inc. Republic of Korea). It is classified as temporary resin, type 1, by ISO 10477. It is a non-transparent resin that cures by itself in the mouth cavity. The product uses temporary crowns, bridges, inlays, onlays, and veneers. There are a total of six different colours in it. 2- Voco acrylic resin temporary material (Structure 2 SC/QM) (VOCO GmbH, Anton - Flettner-Str. 1-3, 27472 Cuxhaven, Germany) is a fluorescent self-curing paste-paste system used to create temporary crowns, bridges, inlays, and Onlays. It was made up of glass particles, BHT, Bis-GMA, amines, and benzoyl peroxide. It is offered in 8 colours.

The test samples were prepared using three distinct moulds, the first of which was a circular stainless-steel mould with a hole that was 6 mm in diameter and 3 mm in thickness. This mould was used to create the samples for the diametral tensile strength test. The samples for the flexural strength test were prepared using a rectangular mould with the following dimensions: length (25) mm, thickness (2) mm, and width (2) mm. The color-change circular mold has a 5 mm diameter and a 2 mm thickness.

The control samples were fabricated by automixing the A2 shade provisional restorative material in the syringe's mixing tip after attaching the mixing tip to the syringe containing the provisional material. Cover one of the metal plates with a glass slab and position the mould upon it. The material was applied to the corresponding hole of the mould and immediately covered with a second glass slab to ensure smoothness of the provisional restoration surface, after complete setting, remove the specimen carefully, the split mould was opened and the provisional restorative material discs were removed and finished with low-speed rubber points to produce a smooth surface. all samples were double-checked using a caliper (Rohde & Schwarz USA).

The modified samples were prepared in a ratio of 1:20 with the incorporation of silica nanoparticles at 5 % by weight to the provisional material using a sensitive digital balance (AOSTE Model Number. HS China). Silica nanoparticles in gel form were purchased from Nano-Tech., Egypt (Nanotech. Company, 6th of October, Egypt). The provisional restorative material is weighted before mixing using a sensitive digital balance. Each 200mg of provisional restorative material needed 10 mg of silica nanoparticles. The provisional restorative material and the silica nanoparticles were pre-weighted before mixing using a sensitive digital balance. The mix was done using a spatula (Garl Martin Gmbh, Germany) on a mixing glass slab. The provisional restorative material modified with silica nanoparticles was ready for manipulation. The modified material was manipulated in the same way as the control samples.

Diametral tensile strength test:

Utilizing a universal testing device (Instron, industrial manufacturing, Norwood, USA), a diametral tensile test was conducted, and information was captured utilizing software (Instron, Bluehill 2014). A computer-controlled universal testing device was used to conduct the test. The specimens were positioned on the universal testing machine's plate such that their diameter and the direction of the compressive force coincided. The specimens were compressed diametrically at a crosshead speed of 0.5mm/min till fracture. The specimen should be fractured into two halves and the specimens that crashed or fractured into more than two pieces were eliminated from the results. The maximum force applied when the specimen's fractures were recorded and then the diametral tensile test in MPa was calculated through the equation $2P/\pi DT$, where P is the maximum load, D is the diameter of the specimen, T is the thickness of the specimen and π is a constant equal 3.14.

Flexural strength test:

Using computer software (Instron, Bluehill 2014), samples were tested in a universal testing machine (Instron, industrial production, Norwood, USA) by being supported on fixtures with a 2.5 mm thickness on both sides, resulting in a 20 mm supported span. The specimens were then stressed with an indenter with a 1 mm thickness at a loading rate of 0.5 mm/min until a fracture occurred (Figure 1). The following equation was used to calculate the flexure strength after recording loads at fractures:

$$\sigma = \frac{3fl}{2bd^2}$$

Where ***F*** is the load (force) at the fracture point**.**
L is the length of the supported span.
b is the width of the specimen.
d is the thickness of the specimen.

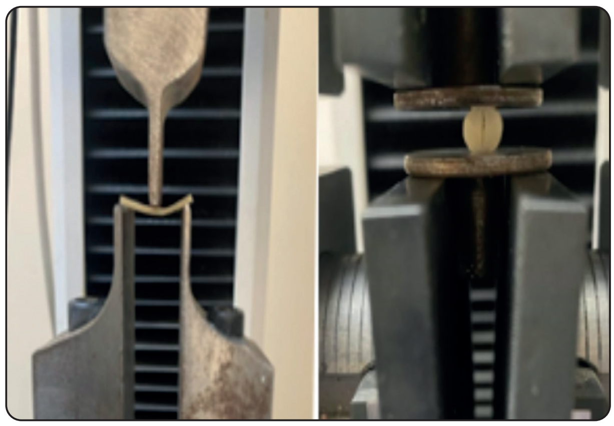

Fig. (1). Measurement of flexural strength and diametral tensile strength

Colour change test

All samples underwent colour parameters measurement using the Spectrophotometer (Cary 5000, USA)). The formula used to compute the colour change (E) is as follows: $\Delta E=[(\Delta L)^2 +(\Delta a)^2 +(\Delta b)^2]^{1/2}$; where E=color change and L=lightness difference (L*), where L* values are proportional to sample brightness; Positive L values for an indicate more red samples, whereas negative values indicate a greener shift in the data. a=axis a* difference. L=L*FL*I; a=a*Fa*I; b=b*Fb*I; where L*I, a*I, and b*I are referred to as the control colour measurement and L*F, a*F, and b*F as the modified colour measurement. b=axis b* difference; positive values for b imply yellower samples and negative values means more shifted towards the bluer side.

RESULTS

Statistical method

Statistical Package for Social Sciences (SPSS) application, version 25, was used to code, tabulate, and statistically analyze the obtained data. Using parametric (normally distributed) quantitative data, descriptive statistics were performed using the mean, SD, and minimum and maximum of the range. The Independent Samples T-test was used to analyze quantitative parametric data comparing the two groups. The significance threshold was set at (A p-value 0.05).

Comparison of Diametral tensile strength between different groups

Diametral tensile strength results showed a significant increase in modified samples (11.4±1.7, 14.2±3.7) in comparison with control samples (6.1±1.7, 8.3±2.2) in both charm and voco provisional materials, respectively. (Table 1, Figure 2)

Comparison of flexural strength between different groups

The flexural strength showed a non-significant decrease in modified samples (59.4±4.1, 33.5±4.9) in comparison with control samples (62.7±1.2, 42.1±11) in both charm and voco provisional materials, respectively. (Table 2, Figure 3)

Comparison of color change (ΔE) between both provisional materials

Between the two provisional materials, there was a statistically significant difference in the colour change (ΔE) value. When compared to the intraorally clinically approved range, the colour change value of the charm provisional material increased (5.1±1.7). (3.3). whereas colour change (ΔE) of voco provisional material (2.4±0.8) was within the intraorally clinical accepted range (3.3). (Table 3, Figure 4)

TABLE (1) The diametral tensile strength (MPa) ± SD of the control and modified samples in both provisional materials.

	Control Charm	Modified Charm	Control Voco	Modified Voco	P value			
	N=5	N=5	N=5	N=5	Cham Control vs VOCO Control	Cham Modified vs VOCO Modified	Cham Control vs Cham Modified	VOCO Control vs VOCO Modified
Diametral tensile strength	(4.1-7.6) 6.1±1.7	(9.3-13.5) 11.4±1.7	(4.5-10.2) 8.3±2.2	(10.6-18.6) 14.2±3.7	*0.123*	*0.172*	***0.001****	***0.014****

Comparing quantitative data between the two groups using independent samples T-test *: At a significant threshold of P < 0.05

TABLE (2) The flexural strength (MPa) ± SD of the control and modified samples in both provisional materials.

	Control Charm	Modified Charm	Control Voco	Modified Voco	P value			
	N=5	N=5	N=5	N=5	Cham Control vs VOCO Control	Cham Modified vs VOCO Modified	Cham Control vs Cham Modified	VOCO Control vs VOCO Modified
Flexure strength test (MPa)	(61.4-64.3) 62.7±1.2	(54.7-63.9) 59.4±4.1	(28.4-57.2) 42.1±11	(28.4-40.1) 33.5±4.9	***0.013****	***<0.001****	*0.150*	*0.151*

Independent Samples T-test for quantitative data between the two groups *: Significant level at P value < 0.05

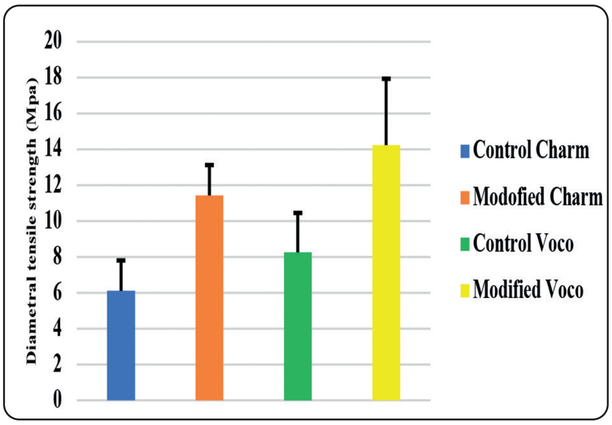

Fig. (2): Histogram showing a comparison of the diametral tensile strength in modified and control samples.

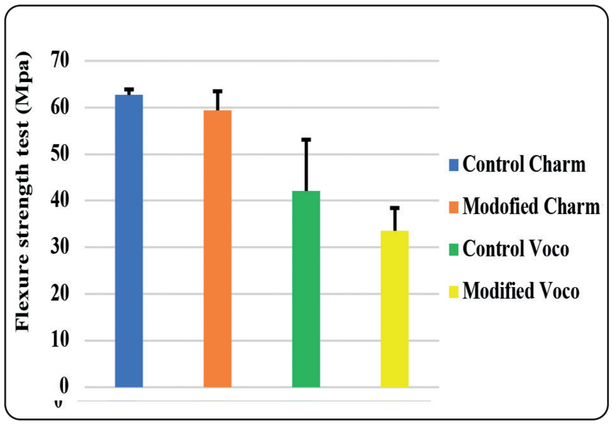

Fig. (3): Histogram showing a comparison of the flexural strength in modified and control samples.

TABLE (3) Comparison between mean colour change (ΔE) of both provisional materials.

		Charm	Voco	P value
		N=5	N=5	
Delta E	Range Mean ± SD	(3.3-7.6) 5.1±1.7	(1.6-3.4) 2.4±0.8	***0.010****

Independent Samples T-test for quantitative data between the two groups

****: Significant level at P value < 0.05***

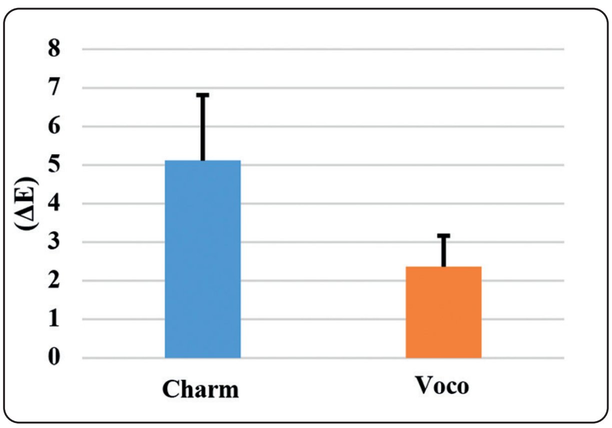

Figure 4: Histogram compared the mean colour change (ΔE) of two provisional materials.

DISCUSSION

Nanoparticles (NPs) have innovative uses in periodontology, endodontics, implantology, restorative dentistry, prosthetic dentistry, and oral malignancies. Due to their ability to combat bacteria, viruses, and fungi, nanoparticles have a huge potential. These nanoparticles improve a restorative material's mechanical characteristics. [17]

Due to its distinctive qualities, the high rigidity of silica nanoparticles is among the most promising and extensively researched ones. Because of their size, surface area, biocompatibility, low toxicity, low density, and adsorption capability, silica-based NPs play a vital role in nanotechnology. [18]

As they offer temporary protection for prepared teeth until permanent prostheses, interim restorations are crucial in fixed prosthodontics. Although the final prosthesis is typically implanted within a brief period of time, typically two weeks, there are a number of circumstances where issues relating to patients or laboratory operations may significantly lengthen the process. Additionally, in difficult prosthodontic procedures, interim restorations must be left in place for months for either therapeutic or diagnostic objectives. [19] To satisfy the demands of patients and the expectations of dentists, interim restorations in each of these situations must maintain structural and functional performance and integrity.

When interim crowns and bridges are meant to be utilized for a longer length of time, colour changes might cause aesthetic issues. Provisional restoration discolourations may be caused by the patient's diet, oral hygiene practices, and the structural characteristics of the material employed. Spectrophotometers provide readings in CIELAB units, which may be quantitatively evaluated to compare the colour characteristics of various objects. [20]

Charm Temp provisional restorative material is a material used for making temporary crowns for crown and fixed dental prosthesis cases. It can also be used for trial veneer cases. It is a self-curing product that has high strength, low shrinkage, high standard flexural strength and various shades for aesthetics (A1, A2, A3). It provides temporary protection for teeth during the operation. A temporary material for crowns and fixed dental prosthesis that satisfies all requirements is Voco Structure 2 SC. It is a versatile, affordable crown and fixed dental prosthesis material for inlays, onlays, and interim crowns. It is simple to finish and polish, fast to handle, inexpensive and sanitary to apply, quick to set in the mouth, has good form and shade stability, outstanding aesthetics, a broad variety of hues, and natural fluorescence. [21]

Flexural strength was chosen in this study for the measurement of mechanical property as it is very important to predict the performance of the material, especially a brittle material and it is strongly affected by the defect and the flow present in the material. [22] Universal testing machine was suited for several testing applications and can do tensile and compressive testing with attachments that support additional tests including flexural tests in some versions, it was utilized to measure the flexural strength and the diametral tensile strength. [21]

In both provisional materials, the findings revealed that modified samples had greater diametral tensile strength than control samples. The high concentration of nanoparticles may play a dual role in controlling the pressing stresses (on the hypothetical Y-axis of load direction) and the increasing distance (on the hypothetical X-axis of load direction) between the polymer chains, which could otherwise result at the moment when defects appear and inevitably cause the material to fail. This may explain why the diametral tensile strength is higher for modified samples. This proves that materials with a high filler content have better mechanical characteristics because more nanoparticles will result in stronger polymer chains and delay the emergence of microcracks. [23] This result is in line with the findings of several other studies that claimed that adding different nanoparticles to composite resins improved their mechanical properties.[21,24] However, other researchers have asserted that nanoparticles did not improve the mechanical properties of the resin matrix. [25]

The study's findings on flexural strength revealed a non-significant loss of flexural strength in modified samples compared to the control samples. Insufficient filler dispersion and aggregation in the acrylic matrix have been suggested as probable causes of the negative impact of silica on flexural strength. This reduction in flexural strength may be explained by these factors. A further factor that might affect the interlocking of fibers and function as a stress-concentrating agent in the acrylic resin is agglomerated fillers sandwiched between polymeric chains. This could impair the material's ability to flex. [26] This is consistent with the findings of Mc Nally et al. [27] and Mansour et al. [28] Tahereh et al. (2015) [29] and Pinar et al [30]. Da Silva et al.[31]

achieved contrasting findings, however, showing that silica powder enhanced the flexural strength of acrylic resins.

To get the best cosmetic features, restorative materials should closely resemble the optical properties of natural tooth structures. However, the dispersion of reinforcing particles might cause dental materials to change colour. [32,33]

The colour change findings demonstrated that adding 5 wt % SiO2 nanoparticles had no effect on the colour of the voco provisional material (2.40.8), where the values were lower than the clinically unnoticeable threshold average of (3.3), proving that the addition of silica nanoparticles to the samples of voco provisional material did not alter the colour. This implies that in the oral cavity neither the dentist nor the patient will likely be able to notice these hue changes. This may be explained by the fact that materials with the smallest-sized reinforcing agent had the greatest overall light transmission values and the least amount of internal light scattering. The findings of this study were consistent with those of Arikawa et al.[34], mami et al.[35], and Kotanidis A et al. [36], who reported that reinforcement of the PMMA resin for interim restorations with SiO2 nanoparticles resulted in significantly lower colour change as expressed with the ab value compared to the upper clinically acceptable values of 3.3.

When compared to the intraorally clinically acceptable range(3.3), the findings of charm temp colour change revealed a increase in colour change value (5.1±1.7). One likely reason is the material's multiple scattering of light, which causes the transmitted light to diffuse. The quantity of the reinforcing component in composite resins, as well as its form and size, directly correlate with the light scattering. [37] Contrary to larger-sized and spherical reinforcing agents, materials with smaller quantities of irregular-sized reinforcing agents showed a significant wavelength dependency of the light transmission. The spectral distribution of light transmitted through the material might change significantly depending on the size and form of the reinforcing agent. The precise surface area of the reinforcing ingredient influences colour variations as well. 35 Typically, the form of the reinforcing agent and its particular surface area are intimately related. A reinforcing agent with an uneven surface and an amorphous form have a higher surface area than one with a smooth surface and a spherical shape. High fluctuations in (ΔE) are associated with larger surface areas.[36] In addition the difference in color change between charm and voco provisional material may be attributed to the difference in optical properties and composition of both materials.

According to the above-mentioned discussion, the hypothesis was rejected in this investigation.

There may be some possible limitations in this study regarding the size and shape of the samples, as they were not simulating those in the patient's mouth, in addition, the samples were not exposed to the same environment or forces in the oral cavity. As the forces in the oral cavity are subjected to a different type of stress analysis. Also, the samples weren't subjected to any type of aging which may lead to unpredictable long-term Serviceability of the modified provisional materials.

CONCLUSIONS

The following finding was reached within the limitations of this study:

1. Addition of silica nanoparticles to both provisional materials significantly improve the diametral tensile strength, whereas decrease flexural strength insignificantly
2. The addition of silica nanoparticles to voco provisional materials leads to colour change within the acceptable clinical average range whereas in charm provisional material was above the clinically accepted range and can be detected by the naked eye.

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