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The effect of natural bioactive additives on the mechanical properties and optical and surface properties of conventional glass ionomer cement

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Abstract---Objectives: To determine the effect of natural bioactive additives on the optical, mechanical, and surface characteristics of standard GIC. Materials and methods: The study included four tested groups: nano-hydroxyapatite (n-HA), Carumcarvi L. (Caraway), (Thymus vulgaris L) Thymol, and (Sesamum Indicum L) Sesame oils, and one control. The following parameters were evaluated: Diametral tensile, shear, Compressive, bond strength, solubility, Surface Roughness, and Color Stability. Results: Mechanical characteristics decreased significantly ($p \leq 0.05$) in all adjusted cements compositions. Solubility and sorption were increased significantly ($p \leq 0.05$) in all amended cement formulations except HA, which showed a non-significant rise in Water Sorption% and Solubility. Color difference mean values are clinically inappropriate ($E > 3.3$). The mean for 1 and 3% sesame oil-modified cement was lower (3.86 1.44 and 4.11 1.70, respectively). Surface roughness showed a significant difference between groups. Conclusion: Natural bioactive additions added to traditional glass ionomer cement did not improve its mechanical, optical, or surface qualities.

Keywords---conservative dentistry, mechanical properties, nano Hydroxyapatites, Glass Ionomer Cements, Carum carvi, Thymol, Sesame oils.

Introduction

The effectiveness of the recently created atraumatic restorative treatment (ART) procedure (GICs) depends heavily on the performance of glass ionomer cements [1]. The ART method involves hand tools being used to remove diseased, infected, and carious dentin before filling the cavity with a fluoride rich GIC material [2]. Ion exchange and chemical interaction occur between GICs and tooth hard tissue [3]. However, these materials offer a few advantages, including excellent thermal expansion and contraction [5, 4], the ability to release and swallow fluoride ions, and chemical attachment to dentin [4. Glass ionomer cements were highly sensitive to moisture, fractured easily, and had poor wear resistance; as a result, they needed a lot of protection to prevent overhydration [6]. GICs are somewhat brittle due to the reaction of the materials' metal ions with the carboxylic group. GICs are rather brittle when the carboxylic group of the materials combines with the metal ions to form stable salts that can attach to mineralized tooth structures [7]. The delayed general acceptance of the materials is most likely due to such problems [8].

The cement powder and liquid have undergone a number of alterations, such as the inclusion of bioactive apatite, zirconia, silica, zinc, fibres, strontium oxide, and nanocrystals [9], to get around these limitations. As a result, anterior and posterior restorations of deciduous and permanent teeth may now be advised using glass ionomer cement[10]. Numerous experiments have been done to alter different characteristics to enhance its mechanical properties. The crucial aspect concerned the inclusion of forcing phase components including metal particles, fibers, and ceramics. The crucial area was the incorporation of forcing phase components such fibers, ceramics, and metal particles [11]. Researchers tried to look into how adding hydroxyapatite influenced GIC behavior because of its great biological effects and crystal structure's similarity to that of human teeth [12]. Sesame oil appears to be high in phosphorus, iron, magnesium, calcium, manganese, copper, and zinc, yet it is one of numerous natural oils that have been demonstrated through various in-vitro experiments. Sesame oil displayed antimicrobial effect through viscosity and an emulsification process in addition to its bioactive component [13]. With better oral hygiene, it is feasible to minimize bacterial adherence to tooth structure [14].

Despite this, studies are being conducted to ascertain sesame oil's impact on lowering Despite this, because of sesame oil's antimicrobial and antioxidant characteristics, research is being done to investigate its impact on reducing plaque formation and dentin hypersensitivity [15]. Caraway essential oil's biological properties, as an antibacterial, antifungal, and antimicrobial agent [16]. Caraway extracts and essential oils could diminish the inflammation of White blood cell and infiltration in mucosa, also, submucosal layers were reduced by essential oils [17]. The immunological properties of caraway have been proven [18]. Also, it was looked at if adding nano-HA particles to GIC may serve as ideal materials to keep enhancing its fluoride content, ion release, mechanical capabilities, and ability to stop lingering bacteria in dentine [19]. However, no studies have been done to find out how its bioactive component directly impacts the properties of dental restorative materials. Considering, due to the GIC's enhanced mechanical properties, which include bioactive components such nanohydroxyapatite and sesame oil [20]. The purpose of this study was to evaluate the capacity of natural bioactive additives to strengthen conventional GIC or to impact optical and surface qualities. The null hypothesis stated that natural bioactive additives would be incapable of reinforcing conventional GIC or influencing optical and surface characteristics.

Material and Methods

The experimental oil preparation

Alumino-fluoro-silicate glass powder, 95% by weight, with 5% polyacrylic acid powder, is the main component of the traditional glass ionomer restorative cement Fuji IX GP (GC Company, Tokyo, Japan). 10% polybasic carboxylic acid, 40% polyacrylic acid, and 50% distilled water are the liquid ingredients. 3.6 to 1 is the ratio of powder to liquid. The liquid was mixed with the experimental oils. The mixtures were kept on the magnetic stirrer for 24 hours to get a homogenous mix (1 = 1 and 3 = 1 (wt.%)). The use of these various liquid formulations resulted in five distinct groups: the groups included the control Conventional GIC(C-GIC)

and four modified experimental groups: nano-hydroxyapatite (HA), Caraway, Thymol, and Sesame oil (Harraz herbal pharmaceutical company, Cairo, Egypt) were used in the study. Molecular weight: 502.31 g/mol and particle size smaller than 200 nm, provided by nano-hydroxyapatite (n-HA) powder (Sigma, Aldrich, Germany). The experimental oils were incorporated into the liquid of the Conventional glass ionomer restorative for testing.

Preparation of C-GIC control sample

The conventional self-cure glass ionomer cement (C GIC) powder and liquid were combined at a ratio of 3.6 to 1.0 (W/W), as per the manufacturer's instructions. A metal spatula and glass slab were used to combine the liquid and powder at room temperature.

Preparation of C-GIC- with nHA

The nano-hydroxyapatite (n-HA) powder and GIC powder were evenly mixed to create the experimental material powder. The n-HA powder and GIC powder were mixed using a spatula on a glass slab. As per the manufacturer's recommendations, the liquid GIC material and the powder containing n-HA were blended in a 3.6/1.0 ratio. The disc samples were then processed in accordance with prior reports. 300 total samples from each of the five groups. The pursuing characteristics were assessed: Surface Roughness (Ra), Compressive Strength, Hardness, Shear Bond Strength, Water Sorption% and Solubility, Diametral Tensile Strength, Compressive Strength, Hardness, Color Stability.

Mechanical Tests
Diametral tensile strength

50 samples from each of the five groups (n=10) were utilised to make the specimens, which had a diameter of 6 mm and a height of 4 mm. A stainless steel rod with a flat end that was 10 cm wide by 5 cm long and attached to the testing machine's upper movable compartment was used to load the samples diametrically and at a speed of 1 mm per minute till failure. The maximum failure load was calculated using Newtons and converted to millipascals (MPa). The diametral compressive strength was calculated using the equation below:

Figure 1. Sample preparation

$$\delta = 2P/ \pi D T$$

Where, δ = Diametral tensile strength (MPa) P = load at failure (N), π = 3.14, D = disc diameter (mm) and T = disc thickness(mm).

Compressive strength

Each specimen was built using split Teflon moulds that were 4 mm in diameter and 6 mm in height. After that, samples of the materials were incubated for up to three times as long as the setting time at 37 °C and 95% relative humidity. A digital calliper was used to measure the specimens' dimensions after they had been removed from the moulds (Mitutoyo MTI Corporation, Tokyo, Japan). The samples were re-incubated for seven days at 37 °C and 95% relative humidity. Data were collected using computer software (Bluehill Lite Software Instron® Instruments) and a computer-controlled materials testing device (Model 3345; Instron Industrial Products, Norwood, MA, USA).

Then, using a stainless steel rod that was terminated with a flat plate (40 mm x 60 mm) secured to the top moveable compartment of the machine, the samples were statically loaded (in compression) repeatedly until failure. Calculated and converted to MPa was the maximum N failure load that may possibly exist. The sample surface was divided by the measured peak load to get the equation below, which was used to determine the compressive strength: The formula 4P/d2 is used to compute compressive strength (CS), where d is the diameter of the cylindrical specimen and P is the load (in N) at the location of the fracture.

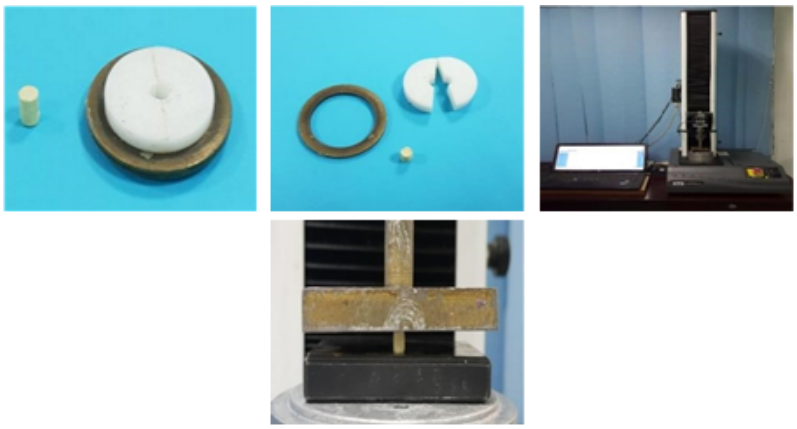

Figure 2. Sample preparation and testing machine

Hardness

With a digital display, the Vickers Micro-Hardness Tester Diagram 3. (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd., China) and a Vickers diamond indenter were used to gauge the specimens' surface micro-hardness. During 15 seconds, a 100g force was applied to the specimens' surfaces. Each specimen's

surface had three indentations drilled into it, each one uniformly spaced around a circle and no more than 0.5 mm apart from the one before it. Using a built-in scaled microscope, the diagonal lengths of the indentations were measured, and Vickers values were converted into micro-hardness values. the micro-hardness that is being assessed; The following equation was used to compute the micro-hardness:

Figure 3. Vickers Micro-hardness Tester

$$HV=1.854\ P/d^2$$

Where, **HV** is Vickers hardness in Kgf/mm^2, P is the load in Kgf and **d** is the length of the diagonals in mm

Interfacial properties

Using a circular interface shear test, the bonding strength, or shear bond tensile strength, was evaluated (MPa). Data were gathered using software while each sample was individually mounted on a computer-controlled materials testing apparatus (Model 3345; Instron Industrial Products, Norwood, USA) (Bluehill Lite; Instron Instruments). Samples were secured to a specially designed sample holder, which was screwed into the lowest fixed compartment of the testing device. At a crosshead speed of 0.5 mm/min and a metallic rod with a single bevel fastened to the testing apparatus's upper movable compartment, shearing tests were conducted. The bond-breaking force was expressed in Newtons. Shear bond strength calculation:

$$\tau = P/ \pi r^2$$

Where, τ =shear bond strength (MPa, P =load at failure (N)

π =3.14 and r =radius of resin disc (mm)

Water sorption and solubility tests

A total, 50 samples of all five groups (n=5) for water sorption and n=5 for solubility test for each group.

Water sorption

The water absorption was calculated using the same method as in the solubility test Figure (4). At 37 ◦ C, the samples (n= 5) were weighed (the beginning weight) and submerged in 20 mL deionized water. The samples were extracted and weighed after 7 days. Three measurements of each weight were taken, and the mean was computed (wet weight). The samples were then dried at 37°C for 72 hours to attain a uniform weight (the dry weight). At each time point, water absorption was calculated as follows:

([wet weight after 7 days - starting weight]/ initial weight) × 100 equals water absorption.

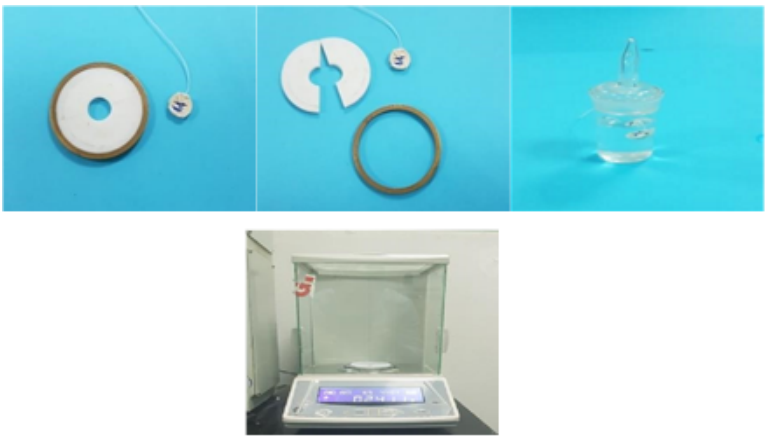

Figure 4. sample preparation and weight measurement

The solubility tests

Mold description: Freshly prepared sealer was poured into circular polytetrafluoroethylene split molds (1.5 mm thick and 7 mm inner diameter). A bigger glass plate supported the mold, which was wrapped in cellophane. Another glass plate covered in cellophane film and a nylon thread were also placed into the material so that the plates evenly touched the mould. During three times the setting time, the assembly was placed in an incubator at 37 degrees Celsius and 95% relative humidity (initial weight). The sealers were removed from the mould and three times weighed precisely to 0.0001 g each (Sartorius, Bio-pharma Laboratory, Germany). The samples were combined with 20mL of deionized distilled water and placed in a glass container. The containers were incubated in an incubator for 24 hours at 37 °C and 95% relative humidity. After being cleansed with deionized distilled water and dried with absorbent paper, the samples were dehydrated for 24 hours before being reweighed (dry weight). For each sealer, the experiment was performed three times. According to ANSI/ADA standard No. 57/2000, the percentage of weight loss of each sample was used to

determine the sealer's solubility. Solubility = ([dry weight after 7days- initial weight]/initial weight) x100. Any specimens that had disintegrated were eliminated, and the test was repeated.

Color Stability and Surface Roughness

A total, 50 samples of all five groups (n=10) for each group.

Color Stability

Discs from each group were created and placed in an 8mm by 2mm split Teflon mould. A spectrophotometer was used to determine the colour coordinates (L, a, and b) for each specimen (Vita Zahnfabrik H. Rauter GmbH and Co. KG, Bad Sackingen, Germany). In order to calculate the colour difference (E), the CIE L, a, and b values of each specimen were compared to those of the control specimen.

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{1/2},$$

Where $L*$ is the color value (lightness) and $a*$ and $b*$ represent chromaticity. Color difference $(\Delta E) \leq 3.3$ is clinically acceptable.

Surface Roughness (Ra).

Utilizing specimens in the form of discs with diameters of 8mm and 2mm, a surface profilometer was used to determine the surface roughness (Mitutoyo Surf Test SJ 210 Analyzer; Mitutoyo Corp, Japan). Each specimen had its five measurements taken five different places, and the average of those measurements was determined. The stylus traced an 8 mm length at a speed of 0.5 mm/s.

Statistical analysis

Data was entered into the computer and examined using IBM SPSS software, version 20.0. New York's Armonk is home to IBM Company. The distribution's normality was verified using the Kolmogorov-Smirnov test. To describe quantitative data, the mean and standard deviation were utilised. The collected results' significance was assessed at a 5% level. The One-Way ANOVA test and the Post Hoc test (Tukey) were both employed to compare more than two groups where the quantitative variables were regularly distributed. Use the student t-test for quantitative variables with normally distributed distributions to compare two studied groups.

Results

There was a significant decrease in mechanical properties (Diametral Strength (MPa), compressive strength, Hardness) ($p < 0.05$) in all formulations of the modified cement (table 1). Regarding Diametral Strength (MPa), Carawya 1 % showed a significant increase in Diametral Strength (MPa) when compared to

control. Shear bond Strength (MPa), Carawya 3 % showed a significant increase in Diametral Strength (MPa) when compared to control. Shear bond Strength (MPa), HA and thymol (table 2) 1 and 3 % showed a significant increase in shear bond strength (MPa) when compared to control. There was a significant increase in Water Sorption % and Solubility % ($p < 0.05$) in all formulations of the modified cement except nano HA that showed non-significant increase in Water Sorption % and Solubility, (table 3).

Color stability, (table 4) shows the color stability results. Student *t*-test revealed a significant difference ($p \leq 0.05$) in HA and Carawya groups, where in thymol and 1 and 3 % sesame oil-modified cement had lower mean (3.86 ± 1.44, and 4.11 ± 1.70 respectively). Color difference mean values of all groups are clinically unacceptable ($\Delta E > 3.3$). Surface Roughness (table 4),Surface roughness (μm), for HA 1, 3 % 0.28^{a} ± 0.0018, and 0.29^{a} ± 0.0018 respectively. Carawya 1, 3 % 0.29^{a} ± 0.0022, and 0.29^{a} ± 0.0019respectively. Thymol 1, 3 0.29^{a} ± 0.0021 and 0.29^{a} ± 0.0021 respectively. Sesame 1, 3 % 0.29^{a} ± 0.0010, and 0.29^{a} ± 0.0024 respectively. A significant difference was observed among groups by ANOVA ($p \leq 0.05$).

Table 1
Comparison between the control and four studied groups according to mechanical properties

	HA	Carawya	Thymol	Sesame
	Diametral Strength (MPa)			
Control	9.44^{a} ± 1.03	9.44^{b} ± 1.03	9.44^{a} ± 1.03	9.44^{a} ± 1.03
1%	3.89^{b} ± 0.08	14.11^{a} ± 2.10	5.08^{b} ± 1.44	3.80^{b} ± 0.11
3%	3.86^{b} ± 0.39	4.64^{c} ± 1.12	3.37^{c} ± 1.12	4.13^{b} ± 0.41
P	<0.001*	<0.001*	<0.001*	<0.001*
	Compressive Strength (MPa)			
Control	38.84^{a} ± 7.02	38.84^{a} ± 7.02	38.84^{a} ± 7.02	38.84^{a} ± 7.02
1%	9.97^{c} ± 0.97	41.56^{a} ± 34.40	25.33^{b} ± 7.47	30.41^{ab} ± 5.29
3%	18.88^{b} ± 0.21	18.16^{a} ± 7.77	17.17^{b} ± 4.59	27.37^{b} ± 0.23
P	<0.001*	0.270	0.003*	0.028*
	Hardness			
Control	57.46^{a} ± 1.53	57.46^{a} ± 1.53	57.46^{a} ± 1.53	57.46^{a} ± 1.53
1%	54.55^{b} ± 2.10	58.29^{a} ± 0.80	56.97^{a} ± 1.08	57.50^{a} ± 2.42
3%	51.27^{c} ± 1.64	57.28^{a} ± 2.49	56.91^{a} ± 2.12	49.70^{b} ± 3.43
P	<0.001*	0.578	0.813	<0.001*

Table 2
Comparison between the control and four studied groups according to interfacial properties

	Shear bond Strength (MPa)			
	HA	Carawya	Thymol	Sesame
Control	0.23a ± 0.09	0.23ab ± 0.09	0.23a ± 0.09	0.23a ± 0.09
1%	0.36a ± 0.08	0.13b ± 0.05	0.32a ± 0.04	0.24a ± 0.02
3%	0.28a ± 0.01	0.26a ± 0.01	0.29a ± 0.09	0.18a ± 0.02
P	0.073	0.042*	0.241	0.350

Table 3
Results for the ANOVA and Tukey post hoc test for water sorption and solubility values for the control and four studied groups

	Water Sorption %			
Control	1.62^{b} ± 0.37	1.62^{b} ± 0.37	1.62^{b} ± 0.37	1.62^{b} ± 0.37
1%	1.48^{b} ± 0.30	3.90^{a} ± 0.37	4.07^{a} ± 0.22	3.05^{a} ± 0.39
3%	3.16^{a} ± 0.29	3.57^{a} ± 0.10	4.41^{a} ± 0.19	3.24^{a} ± 0.29
P	<0.001*	<0.001*	<0.001*	<0.001*
	Solubility %			
Control	2.23^{a} ± 0.44	2.23^{b} ± 0.44	2.23^{b} ± 0.44	2.23^{b} ± 0.44
1%	2.54^{a} ± 0.63	4.96^{a} ± 0.76	2.40^{b} ± 0.17	2.46^{b} ± 0.37
3%	2.73^{a} ± 0.59	2.34^{b} ± 0.23	3.09^{a} ± 0.38	3.74^{a} ± 0.59
P	0.224	<0.001*	0.001*	<0.001*

Data was expressed using Mean ± SD. SD: Standard deviation
F: F for One way ANOVA test, pairwise comparison bet. each 2 groups were done using Post Hoc Test (Tukey)
p: p value for comparing between the studied groups.
*: Statistically significant at $p \leq 0.05$

Means in the same column with Common letters are not significant (i.e., Means with Different letters are significant)

Table 4
Comparison between all studied groups according to optical and surface properties

	HA	Carawya	Thymol	Sesame
Color stability (ΔE)				
1%	20.46^{a} ± 4.16	25.11^{b} ± 7.74	9.92^{a} ± 7.77	3.86^{a} ± 1.44
3%	6.91^{b} ± 2.35	33.18^{a} ± 4.48	4.27^{a} ± 2.10	4.11^{a} ± 1.70

T	8.504*	2.708*	2.104	0.325
P	<0.001*	0.016*	0.064	0.750
Surface Roughness				
1%	0.28^{b} ± 0.0018	0.29 ^{b}± 0.0022	0.29^{b} ± 0.0021	0.29^{b}± 0.0010
3%	0.29 ^{b}± 0.0018	0.29^{b} ± 0.0019	0.28^{b} ± 0.0047	0.29^{b}± 0.0024
P	≤0.0001			

Data was expressed using Mean ± SD. SD: Standard deviation
p: p value for comparing between 1% and 3%
*: Statistically significant at p ≤ 0.05
Means in the same column with Common letters are not significant (i.e., Means with Different letters are significant)

In the present study, Surface roughness (*µm*): Atomic Force Microscope results: (Figure 1-8) show 3-D microphotography of the tested groups a significant difference was observed among groups by ANOVA ($p \leq 0.05$). For HA 1, 3 % 0.28a ± 0.0018, and 0.29a ± 0.0018 respectively. Caraway 1, 3 % 0.29a ± 0.0022, and 0.29a ± 0.0019respectively. Thymol 1, 3 0.29a ± 0.0021 and 0.29a ± 0.0021 respectively. Sesame 1, 3 % 0.29a ± 0.0010, and 0.29a ± 0.0024 respectively.

Surface roughness (*µm*):: Atomic Force Microscope results: (Figure 1-8) show 3-D microphotography of the tested groups.

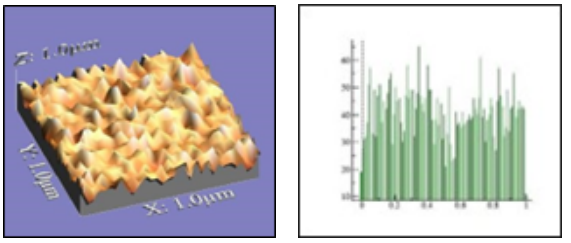

Figure 1. 3-D microphotograph of 1% hydroxyapatite mean surface roughness(Ra)= 0.2911 µm and Histogram of 1% hydroxyapatite (1.0µm)

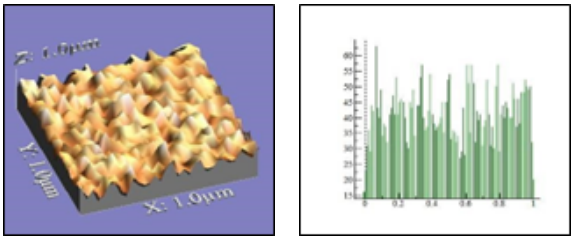

Figure 2. 3-D microphotograph of 3% hydroxyapatite mean surface roughness(Ra)= 0.2908 µm and Histogram of 3% hydroxyapatite (1.0µm)

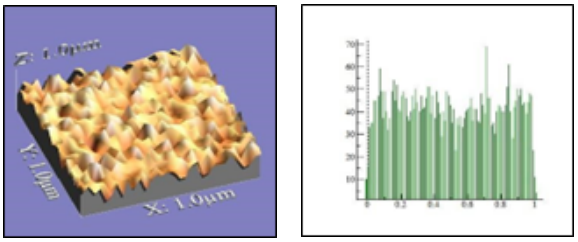

Figure 3. 3-D microphotograph of 1% thymol mean surface roughness(Ra)= 0.2914 µm and Histogram of 1% thymol (1.0µm)

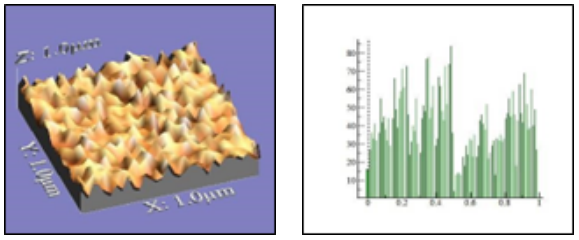

Figure 4. 3-D microphotograph of 3% thymol mean surface roughness(Ra)= 0.2893 µm and Histogram of 3% thymol (1.0µm)

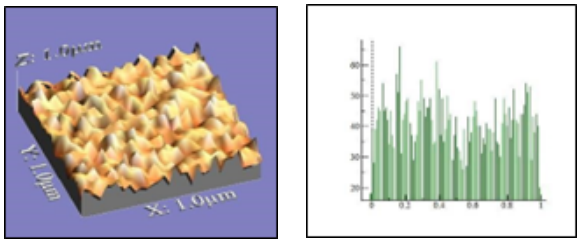

Figure 5. 3-D microphotograph of 1% sesamum mean surface roughness(Ra)= 0.2915 µm and Histogram of 1% sesamum (1.0µm)

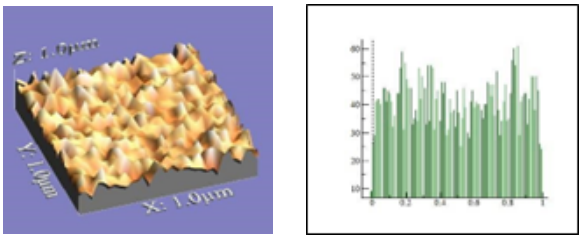

Figure 6. 3-D microphotograph of 3% sesamum mean surface roughness(Ra)= 0.2932 µm and Histogram of 3% sesamum (1.0µm)

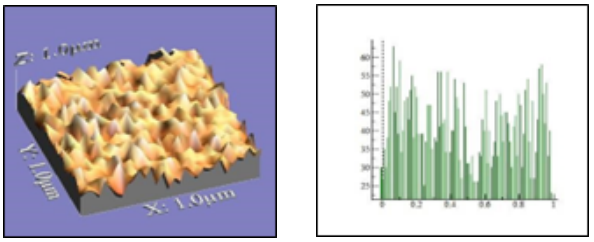

Figure 7. 3-D microphotograph of1% *Carum carvi* mean surface roughness(Ra)= 0.2921 µm and Histogram of 1% *Carum carvi* (1.0µm)

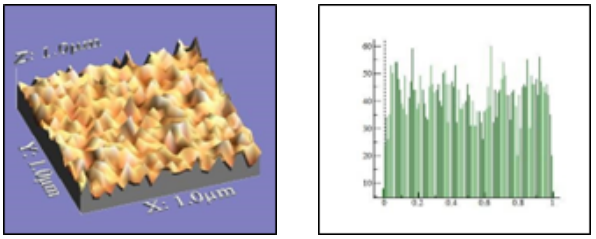

Figure 8. 3-D microphotograph of3% *Carum carvi* mean surface roughness(Ra)= 0.2894 µm and Histogram of 3% *Carum carvi* (1.0µm)

Discussion

The distinguishing characteristics of GICs are biocompatibility, long-term fluoride release that serves as an anticariogenic agent, flexibility like dentin, and direct connection to tooth structure [21]. For such reasons, GICs are a common substance used in dentistry [22]. These materials are often utilized as luting cement, atraumatic restorative therapy (ART) materials, lining and base materials, fissure sealants, and restorative materials in pediatric dentistry [23]. A popular material for the ART technique has been Fuji IX, a high viscosity glass ionomer cement (HVGIC) [24]. Despite their advantages, they have several disadvantages, including a high solubility and a slowdown setting rate, as well as poor mechanical and physical properties (low wear resistance) [25]. Their broad use as a stress-bearing filler material in dentistry has been hampered as a result. In order to improve GIC mechanical properties, various studies have tried to change the chemical makeup of polyalkenoic acid or ionomer glass [26]. Based on its antibacterial and antioxidant properties, sesame oil has been the subject of prior studies [27,28] that looked at how it affected plaque development and dentin hypersensitivity. Aref [29] look at sesame oil's potential as a natural bioactive ingredient to enhance common glass ionomer cement. In order to provide traditional GIC a visually beautiful finish that is therapeutically effective, sesame oil appears to be a feasible natural bioactive component.

Sesame oil has the potential to make cement stronger, tougher, and more scratch-resistant by increasing the degree of interlocking and cross-linking within

the cement matrix. The Ca ion concentration in sesame oil may The Ca ion concentration of sesame oil may lessen the quantity of carboxylic acid required to create poly salt bridges [30]. On the other hand, the rise in bond strength levels might be explained by a different source. Sesame oil's high phosphorus and calcium content may chemically bind with the calcium in tooth structure to improve adherence. [31] Nano bioactive ceramics improved GIC mechanical properties and dentin bond strength, according to Panigrahi et al. [32]. Standard GICs are given HA to enhance their mechanical properties [33]. According to Alatawi et al [34], investigated GICs with different wt% (1:10%) of n-HA, they found that addition of n-HA particles outperformed traditional GIC interms of mechanical properties. As a result, to reinforce traditional GIC while considering the previously enhanced mechanical capabilities of the previously modified GIC with natural bioactive ingredients This investigation was done to determine whether a natural bioactive ingredient may strengthen traditional glass ionomer cement, like sesame oil and carawya [35].

In the current experiment, the mechanical characteristics (Diametral Strength (MPa), Compressive Strength, Hardness, and Shear Bond Strength) of all formulations of the modified cement significantly decreased (p 0.05). Carawya 1% demonstrated a significant increase in Diametral Strength as compared to the control (MPa). Carawya 3% showed a significant increase in Diametral Strength when compared to the control (MPa). Shear Bond Strength (MPa), HA 1 and 3% showed a noticeably higher Diametral Strength when compared to the control (MPa). The findings are in line with those of a different investigation that found that glass ionomer cement's mechanical characteristics were adversely affected when bioactive glass was added [36].

The findings were consistent with those of Elgendy et al. [37], who discovered that decreasing the fine-grit HA particle loading lowered the compressive fracture strength of experimental GICs. A considerable increase in GIC compressive strength was also demonstrated by Khaghani et al. [38] with the HA substitution. Whereas Noori et al. [39] demonstrated that adding the HA powder led to a considerable reduction in compressive fracture and diametral tensile strength after being exposed to water for 24 hours and a week, Water sorption and solubility play a key role in the assessment of bonding materials since they have a direct impact on cement lifespan. During water sorption tests, it is possible to evaluate the net weight increase that a specimen experiences as a result of the diffusion of water molecules and the elution of monomers and other small molecules [40]. In light of polyacrylic acid and GICs to interact, the water sorption mechanism first transfers calcium and aluminum ions into GICs. On the other hand, excessive water absorption over time can result in cement corrosion and degradation, which compromises the structural and mechanical properties [41]. Since other studies have indicated that the maximum amount of water gain occurs within the first week in most hydrophilic materials, the water sorption and solubility of the specimens were investigated after 7 days of immersion in the current examination [42]. At the end of the immersion period, all the tested groups showed greater water sorption than the control in terms of water absorption. They may have undergone a chemical alteration that has altered their water sorption, which is one likely reason [43].

Their altered chemical composition, which altered their propensity to absorb water, is one likely explanation. Natural bioactive additives, such sesame oil, that are present in conventional GIC are distinguished from it by their hydrophilic nature [44]. A substance's ability to dissolve in another substance is known as its solubility, and it is quantified by the concentration of a saturated solution of a solvent in a dissolvent [45]. The mean result for water solubility was positive for each of the studied groups. Positive solubility readings can be attributable to these materials' complete dehydration, showing that solubility took place [46]. The fact that the water molecules were continually linked together to generate the formations is one theory. The materials consequently expanded and became heavier [47]. It was claimed that the old GIC's viscous liquid was a significant factor in the difficult handling and porosity creation during hand mixing. Additionally, larger bubbles have been seen in hand-mixed cement compared to encapsulated forms [48], and this porosity may be one of the reasons for the conventional cement's higher surface roughness rating. The observations on surface roughness provide credence to the idea that natural bioactive additives, such as sesame oil or its constituents, may be to blame for the cement's pores being closed in both tested concentrations together with an increase in packing density [49].

It has been determined that several factors affect surface roughness. Two of these characteristics are the additive's distribution and particle size in the base material [50]. Also, the fact that the GIC used in the study was manually mixed is crucial to take into account since it increases the possibility of porosity forming inside the mixed cement. Although the oil modified GIC groups had lower surface roughness values than the control groups, the compressive strength is high and has sealing capabilities; this may be because the liquid form has the potential to trigger the sealing of the pores within the matrix, resulting in a more cohesive structure [51].

Conclusions

Based on the outcomes of this investigation, the following conclusion may be reached:

- The mechanical qualities of the GIC were not significantly improved by the addition of natural bioactive substances intended to improve them.
- Nano HP improved the GIC's surface properties.
- The compositions of restorative materials have an impact on color stability, surface roughness, and water sorption/solubility.
- Nonetheless, before GIs may be employed clinically for the regeneration of posterior dentition, major improvements in GI compositions using a reinforcing technique are needed.

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