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Evaluation of Some Mechanical Properties of Conventional and Experimental Glass-Ionomer Cement Modified with Sesamum Indicum Extract

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Abstract: Objectives: This study was designed to evaluate the influence of Sesamum indicum extract on the mechanical properties of two formulations of glass ionomer cement. Material and Methods: A total of 90 samples of glass ionomer cement were prepared according to the test type. The samples were divided into 2 equal groups (n=45) according to the type of glass ionomer cement; Group (1): Conventional Glass ionomer cement, Group (2): Experimental Glass ionomer cement. Each group was further subdivided into 3 subgroups (n=15) according to the ratio of Sesame oil, subgroup (A): Glass ionomer cement without Sesame oil, subgroup (B): Glass ionomer cement with Sesame oil ratio1(v/v%), subgroup (C): Glass ionomer cement with Sesame oil ratio 4(v/v%). All the samples were submitted to evaluate the following properties, compressive strength, diametral tensile strength, and shear bond strength. Results: GICs modified with 1(v/v%) Sesame oil exhibited a significant increase in their compressive strength but a significant decrease in diametral tensile strength and a non-significant decrease in shear bond strength. GICs modified with 4(v/v%) Sesame oil exhibited a significant decrease in compressive strength, and diametral tensile strength, while a non-significant decrease in shear bond strength. Conventional glass ionomer cement exhibited significantly higher compressive strength than the experimental one but was not significantly lower in diametral tensile strength and shear bond strength. Conclusions: Sesame oil enhanced the compressive strength at low concentration with no significant effect on shear bond strength, while it showed a weakening effect on compressive strength at high concentration and determinal effect on tensile strength at both concentration for both glass ionomer cement formulations.

Keywords: glass-ionomer cement, Sesamum indicum extract, compressive strength, diametral tensile strength, shear bond strength.

Introduction: Two aesthetic restorative materials, resin-based and water-based glass ionomer cement (GIC) are being used as alternatives to old metallic restoration due to its deleterious effects on patient health. 1 Conventional GIC is a composite material formed by acid-base reaction between aqueous solutions of polyacrylic acid (PAA) and ion-leachable glass powder. 2

Glass ionomer cement is widely used in dentistry for different purposes including restorative materials, liners and bases, luting agents, fissure sealants, and adhesives for orthodontic brackets because of its unique properties like chemical adhesion, biocompatibility, remineralization of dental tissues, coefficient of thermal expansion similar to the tooth structure, and anti-cariogenic activity that is due to its fluoride release.3

Despite their advantages, they have some limitations such as susceptibility to dehydration, poor physical (high solubility and slow setting rate), and mechanical properties (low wear resistance) that limit the conventional GICs to be used only at certain low stress-bearing sites such as class III and class V cavities.4 Since the invention of GIC, numerous developmental trials have been attempted by adding filler components such as silver amalgam particles, silica, zirconia, glass fiber, hydroxyapatite, and bioactive glass particles. The incorporation of these filler particles to GIC has significantly modified the physico-mechanical properties of cements.5

Recently, natural oils have been used in an attempt to improve the properties of glass ionomer, especially Sesame oil because it is rich in minerals, including manganese, copper, zinc, iron, magnesium, and phosphorus. Due to its viscosity and emulsification process, sesame oil has been shown to have antibacterial properties that reduce bacterial adhesion to tooth structure while improving oral hygiene. Additionally, it has vitamin E and certain amounts of unsaturated fatty acids able to reduce the free radical injury of oral tissues.6,7

Although previous researches investigated the effect of sesame oil on biological properties and dentin hypersensitivity depending on antibacterial and antioxidant action.6,7,8 However, no researches evaluated its influence on the mechanical properties of glass ionomer cement. Therefore, the current study was intended to determine the ability of Sesame oil to reinforce glass ionomer cement. The null hypothesis was that Sesame oil would not be able to reinforce GIC.

Materials and Methods:

Ethics Committee Approval: The ethical approval for the study was obtained from the Research Ethics Committee, Faculty of Dental Medicine for girls, Al-Azhar university. The committee met on January 2024(REC-MA-24-01)

Two materials were used in this study; conventional glass ionomer cement powder and liquid (Prevest Den Pro Limited, Jammu, India), experimental glass ionomer cement prepared by sol-gel method, and Sesame oil (Harraz herbal pharmaceutical company, Cairo, Egypt).

Samples grouping:

A total of 90 samples of glass ionomer cement were used in this study. The samples were divided into 2 equal groups (n=45) according to the type of glass ionomer cement based on power analysis and sample size calculation in a previous study.[9] Each group was further subdivided into 3 subgroups (n=15) according to the ratio of Sesame oil. All the samples were submitted to evaluate the following properties, compressive strength, diametral tensile strength, and shear bond strength.

Group (1): Conventional Glass ionomer cement (n=45).

Subgroup (A): Conventional Glass ionomer cement without Sesame oil (n=15).

Subgroup (B): Conventional Glass ionomer cement with Sesame oil ratio 1(v/v%) (n=15).

Subgroup (C): Conventional Glass ionomer cement with Sesame oil ratio 4(v/v%) (n=15).

1) **Group (2)**: Experimental Glass ionomer cement (n=45).

Subgroup (A): Experimental Glass ionomer cement without Sesame oil (n=15).

Subgroup (B): Experimental Glass ionomer cement with Sesame oil ratio 1(v/v%) (n=15).

Subgroup (C): Experimental Glass ionomer cement with Sesame oil ratio 4(v/v%) (n=15).

Preparation of glass powder by sol-gel method:

Glass powder was prepared by sol-gel method for preparation of 100gm of sol-gel formulated glass ionomer cement powder (50%SiO_2,15% Al_2O_3, 20%CaO and5% P_2O_5,10% Na_2O) various reagents and solutions with specific concentration were selected as a source supply of SiO_2, Al_2O_3, CaO and P_2O_5, Na_2O (all chemicals used were manufactured by Sigma-Aldrich, St. Louis, MO, USA).

Two Solutions were made. Solution (A) from mixing 18.795ml tetra ethyl ortho silicate (TEOS) with 19.486 ml distilled water and 4.19 ml from nitric acid (HNO_3) (as hydrolysis catalyst) together in ethanol were kept on the magnetic stirrer at 1500 rpm for 45 minute. After that amount of 1.19 ml from TEP, 8.507gm $Ca\ (NO_3)_2 \bullet 4H_2O$ then 2.769 gm $NaNO_3$ were added to mix allowing 45 minutes for each one to react completely. Solution (B) from mixing 11.148gm $Al\ (NO_3)_3.9H_2O$ with distilled water, then added to Solution (A) for 45 minute under continuous magnetic stirring. After the final addition, the mixtures of all reagents were left under continuous magnetic stirring for 60 minutes to complete hydrolysis. An amount of 4.19 ml of ammonia solution (as a gelation catalyst) was dropped into the mixture.[10]

The mixture was then agitated with a glass rod to prevent the formation of a bulked gel. Finally, the prepared gel was left to dry at 100° C to 120° C for 2 days and sintered at 580° C for 2 hours in a thermal oven. Then, the sintered powder was ground into a fine powder using laboratory mortar and pestle and then was passed through a sieve with a mesh number 325 mesh to give a particle size of less than 45 µm.[11]

Characterization of glass ionomer cement:

Characterization of the conventional and experimental powders of glass ionomer cement was made by X-ray diffraction (XRD) (X'Pert^3 MRD, United Kingdom, Europa) to identify the nature of glass (amorphous or crystalline). Also, Fourier transform infrared (FTIR) spectroscopic analysis (Thermo scientific™ Nicolet™ iS™50 FTIR, United Kingdom, Europa) was used to determine the functional group. A representative sample of each subgroup and a sample of sesame oil were explored for their chemical structure by (FTIR).

Modification of glass ionomer cement with Sesame oil:

Sesame oil was incorporated into the liquid of glass ionomer cement with both concentration;

1 and 4(v/v%) using the magnetic stirrer for 24 hours to obtain a homogenous mix.

Sample preparation:

Compressive Strength test:

A specially designed Teflon mold was constructed to form cylindrical samples with dimensions of 3 mm in diameter and 6 mm in height. The conventional and experimental GIC powder was mixed with commercial glass ionomer liquid according to the manufacturer's instructions. The mixed cement was condensed in the Teflon mold which was placed on a glass plate. Samples were covered with celluloid strip and pressed with another glass plate. The samples were removed from the mold after setting and stored in distilled water for 24 hours before testing [(12,13)]. Compressive strength was assessed by a Universal Testing Machine (Instron Industrial Products, Norwood, MA, USA). The compressive load was applied to the specimen at a crosshead speed of 1 mm/min until fracture. Compressive strength was calculated according to the following CS = 4P/πd2; Where (CS) is the compressive strength (MPa), (P) is the load at the fracture point (N), (d) is the diameter (mm) of the sample and (π) is a constant = 3.14.[12]

Diametral tensile strength test:

A specially designed Teflon mold was prepared to form disk samples with dimensions of 4 mm in diameter and 2 mm in height. The disc sample was mounted on the mechanical testing machine and the load was applied to the samples using a cross head speed of 0.5 mm/min applying a compressive force on the samples until fracture. The diametral tensile strength was calculated in (MPa) using the following equation's = 2P/πdt; Where (DTS) is the diametral tensile strength (MPa), (P) is the load (N) at the fracture point, (d) is the diameter (mm) of the samples, (t) is the height (mm) of the samples.[13]

Shear bond strength test:

Thirty human permanent mandibular molars were collected, Molar teeth were freshly extracted and had no decay, crack, or structure deformities and stored in normal saline and chloramine-T until use. After removing any tissue tags the teeth were cleaned with pumice. Then, the roots of each tooth were embedded in a chemically-cured acrylic resin block. Occlusal grinding was done by silicon carbide disc to expose superficial dentine. The exposed dentin surface was conditioned by polyacrylic acid for 20 sec. After that, cylindrical samples (5mm diameter x 2mm length) of GIC were constructed over the flat dentine surface using a special Teflon mold and stored in distilled water for 24 hours. Then, the shear bond strength test was determined via a testing machine at cross head speed of 0.5 mm/min.[14] The shear bond strength was calculated as follows.

$$\tau = P/\pi r2$$

where τ is the shear bond strength, P is the load at failure (N), and r is the radius of the specimen (mm).

Statistical analysis:

The results were analyzed using Graph Pad Instat (Graph Pad, Inc.) software for windows. A value of $P < 0.05$ was considered statistically significant. Continuous variables were expressed as the mean and standard deviation. After the homogeneity of variance and normal distribution of errors had been confirmed, a one-way analysis of variance was performed followed by Tukey's post-hoc test if showed significance. Student t-test was done for compared pairs. Two-way ANOVA compared the effect of each factor (material and concentration). The sample size (n=15/group) was large enough to detect large effect sizes for main effects and pair-wise comparisons, with a satisfactory level of power set at 80% and a 95% confidence level.

Results and Discussions:

Characterization of glass ionomer cement:

XRD analysis:

The XRD patterns of the experimental GIC powder sample show no diffraction peaks were observed, indicating the amorphous structure of prepared GIC powder shown in Fig.1.

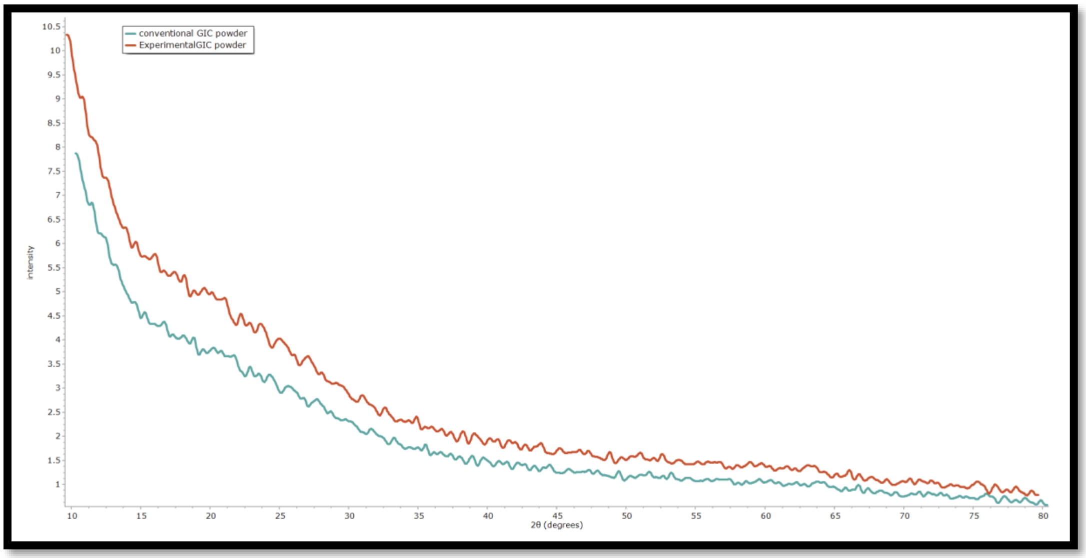

Fig.1.The XRD patterns of conventional and experimental GIC powders.

FTIR analysis:

FTIR spectroscopic analysis of conventional and experimental GIC powder: The transmission FTIR spectra of conventional and experimental GIC powder GIC in the spectral range between 400 cm^{-1} and 4000 cm^{-1}. The presence of well-defined bands at 454 cm^{-1}, is characteristic of silica groups (Si-O-Si and Si-O) (δ) that represent the main constitutional composition of commercial GIC. Moreover, the vibration bands at 718 cm^{-1} and 1033 cm^{-1} are characteristics of symmetric stretching vibration of silica (Si-O). The small peaks at 2854, and 2925 cm^{-1} spectrum duo to symmetric and asymmetric stretching of C-H (υ) group and were weakly observed., Moreover, the analyzed composition powder had a peak at 3465 cm^{-1} which represents the silica hydroxyl (Si-OH) group was observed. Fig.2

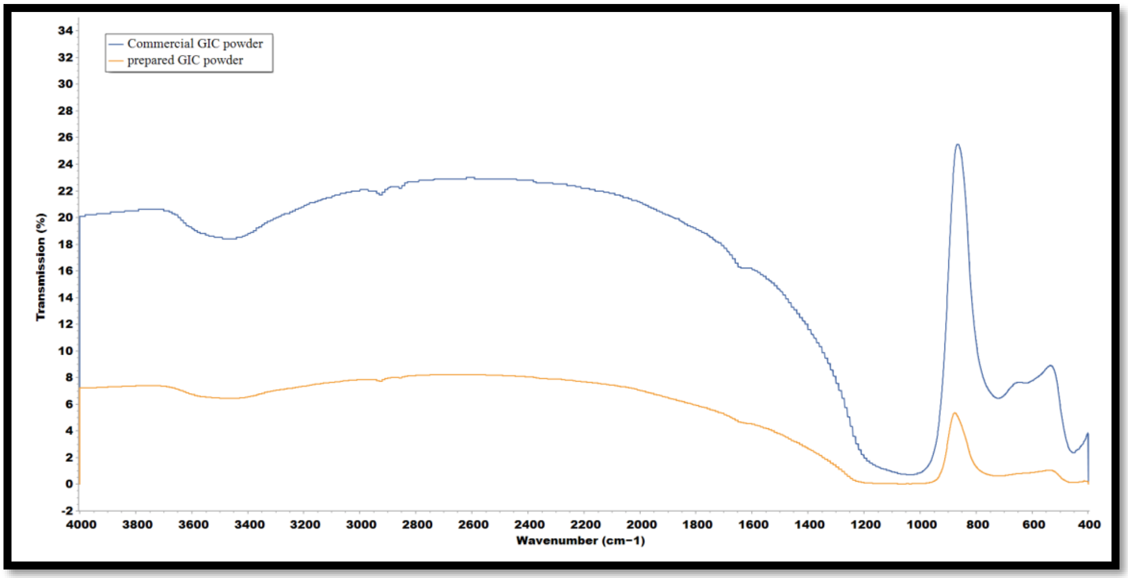

Fig.2.FTIR spectra of conventional and experimental GIC powders.

FTIR spectroscopic analysis of Sesame oil:

The spectrum of Sesame oil revealed the presence of a well-defined absorbance band at 3007 cm^{-1} was caused by stretching vibration of (cis) C =CH, and both peaks at 2923 and 2853 cm^{-1} were originating from asymmetric and symmetric stretching vibrations of methylene (−CH2). At 1746 cm^{-1}, the carbonyl (C =O) stretching vibration was observed, though the peak at 1653 is due to C = C stretching vibration. the bending vibrations of methylene and methyl were obvious at wave numbers 1463 and 1376 cm^{-1}, respectively. the absorbance bands at 1238, 1164, 1119, and 1098 cm−1 were from C-O vibrations. Moreover, peaks at 966 and 872 were a result of bending out of plane vibrations of–HC = CH– (trans) and –HC = CH– (cis), correspondingly. A band at 722 cm-1 is the overlap of CH2 rocking vibration,Fig.3.

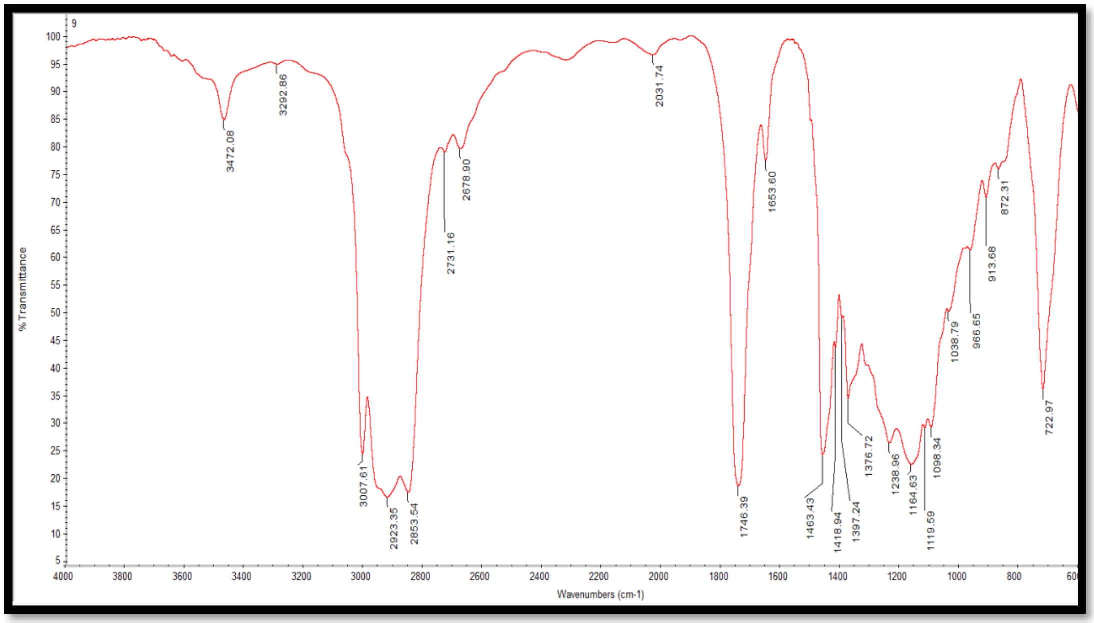

Fig.3.FTIR spectra of Sesame oil.

FTIR spectroscopic analysis of conventional GIC unmodified, 1(v/v%) Sesame oil-modified GICs, and 4(v/v%) Sesame oil-modified GICs.

The spectrum of conventional GIC revealed the presence of a well-defined broad band at 3433 cm^{-1} which represents the Si--OH stretching mode of the OH group shifted to the lower wave number 3419 cm^{-1} and 3424 cm^{-1} in 1 and 4 (v/v%) Sesame oil-modified GICs, respectively. The weak vibrational bands that appear at 2921 cm^{-1} and 2851 cm^{-1} spectrum due to asymmetric stretching and symmetric stretching of the C-H group were nearly the same with no variations distinguished. The vibrational band at 1625 cm^{-1} is related to the presence of asymmetric coo^{-} shifted to the higher wave number 1632 cm^{-1} and 1626 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GICs. while the vibration band at 1461 cm^{-1} is characteristic of the Stretching vibration of C-O shifted to a higher wave number of 1464 cm^{-1} in 1 (v/v%) Sesame oil-modified GICs. On the other hand, the band at 1079 cm^{-1} is characteristic of Asymmetric stretching Si-o-Si shifted to the higher wave numbers 1087,1081 cm^{-1} in 1 and 4 (v/v%) Sesame oil-modified GICs, respectively. The band at 460cm^{-1}which is characteristic for AL-O-AL, Al-O-Si and Si-O-Si shifted to the lower wave number 459 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GICs, the band at 599cm-1 is related to A split of P-O band shifted to 568,584 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GICs.Fig.4.

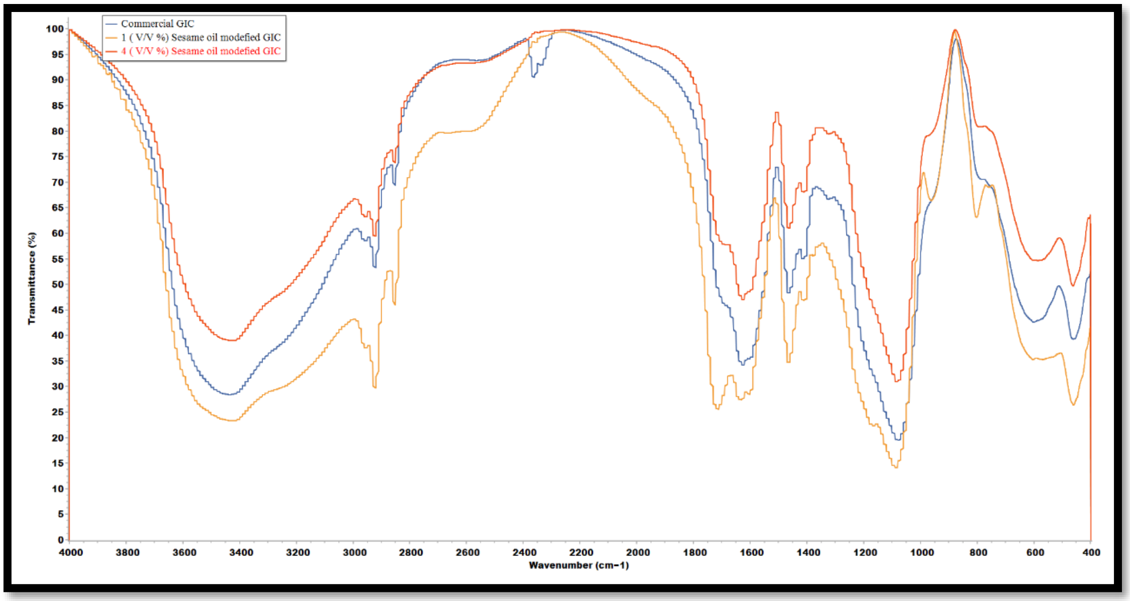

Fig.4.FTIR spectra of conventional GIC unmodified, 1(v/v%) Sesame oil-modified GICs, and 4(v/v%) Sesame oil-modified GICs.

FTIR spectroscopic analysis of experimental GIC unmodified, 1(v/v%) Sesame oil-modified GICs, and 4(v/v%) Sesame oil-modified GICs.

The spectrum of experimental GIC revealed the presence of a well-defined broad band at 3426 cm^{-1} which represents the Si--OH stretching mode of the OH group shifted to the higher wave number 3433 cm^{-1} and 3427 cm^{-1} in 1 and 4 (v/v%) Sesame oil-modified GICs, respectively. The weak vibrational bands appear at 2823, and 2852 cm^{-1} spectrum due to asymmetric stretching and symmetric stretching of the C-H group shifted to 2921 cm^{-1} and 2851 in1 and 4(v/v%) Sesame oil-modified GICs. The vibrational band at 1626 cm^{-1} is related to the presence of asymmetric coo^{-} shifted to the higher wave number 1630 cm^{-1} and 1627 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GICs. while the vibration band at 1461 cm^{-1} is characteristic for stretching vibration of C-O shifted to higher wave number 1462 cm^{-1} in 1 and 4 (v/v%) Sesame oil-modified GICs. On the other hand, the band at 1083 cm^{-1} is characteristic of Asymmetric stretching Si-o-Si shifted to the higher wave number 1086cm^{-1} in 1(v/v%) Sesame oil-modified GICs. The band at 460cm^{-1}which is characteristic for AL-O-AL, Al-O-Si and Si-O-Si shifted to the lower wave number 459 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GICs, the band at 598 cm^{-1} is related to A split of P-O band shifted to 604,605 cm^{-1} in1 and 4(v/v%) Sesame oil-modified GIC. Fig.5

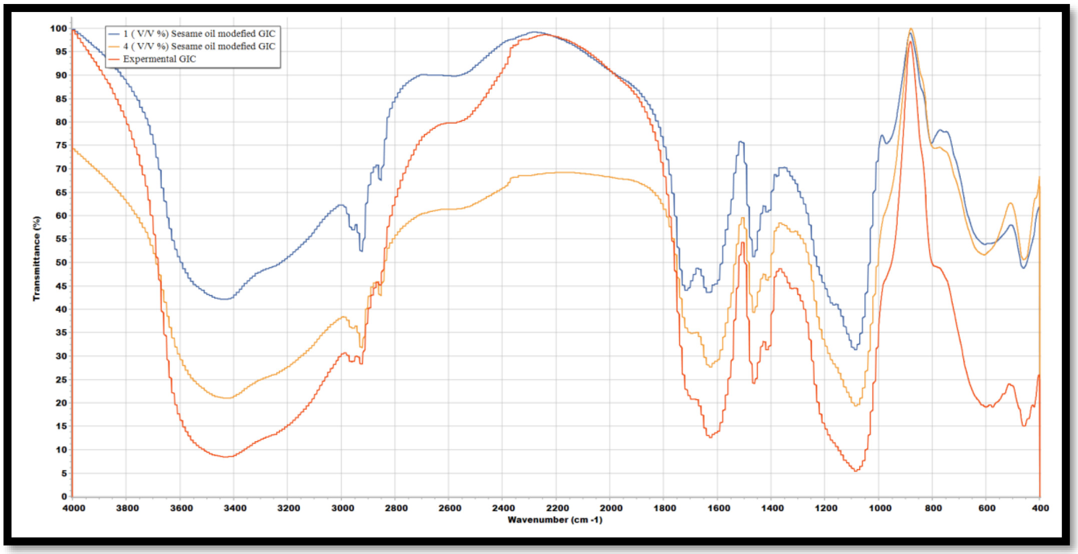

Fig.5.FTIR spectra of experimental GIC unmodified, 1(v/v%) sesame oil-modified GICs, and 4(v/v%) sesame oil-modified GICs.

Compressive strength test results (MPa):

The mean values and standard deviation of compressive strength (MPa) test results for both GIC groups with different Sesame oil extract concentration are summarized in Table 1.

Conventional GIC

It was found that the 1% Sesame oil extract concentration modified subgroup recorded the highest mean value of compressive strength (230.86 MPa) followed by the control (0%) subgroup mean value of (191.28 MPa) meanwhile the lowest mean value was recorded with 4% modified subgroup (160.96 MPa). The difference between different subgroups was statistically significant as indicated by one-way ANOVA followed by Tukey's post-hoc tests ($P=<0.0001<0.05$) as shown in Table 1.

Experimental GIC

It was found that the control (0%) subgroup recorded the highest mean value of compressive strength (168.83 MPa) followed by 1% Sesame oil extract concentration modified subgroup mean value of (158.16 MPa) meanwhile the lowest mean value was recorded with a 4% modified subgroup (145.98MPa). The difference between different subgroups was statistically significant as indicated by one-way ANOVA ($P=0.0111<0.05$). Pair-wise Tukey's post-hoc test showed a non-significant difference between (control (0%) and 1% modified) and (4% and 1% modified) subgroups as shown in Table 1.

Conventional vs. experimental GIC

With 0% Sesame oil modification:

It was noted that the conventional GIC group recorded a higher compressive strength mean value (191.28 MPa) than the experimental one (168.83 MPa) and this was statistically significant as indicated by t-test ($P=0.0137<0.05$) as shown in Table 1.

With 1% Sesame oil modification:

It was noted that the conventional GIC group recorded a higher compressive strength mean value (230.86 MPa) than the experimental one (158.16 MPa) and this was statistically significant as indicated by t-test (P=0.0001<0.05) as shown in Table 1.

With 4% Sesame oil modification:

It was noted that the conventional GIC group recorded a higher compressive strength mean value (160.96 MPa) than the experimental one (145.98 MPa) and this was statistically significant as indicated by t-test (P=0.0322<0.05) as shown in Table 1.

Regardless of Sesame oil extract concentration, it was found that conventional GIC recorded statistically significant higher strength (194.37 MPa) than experimental one (157.65 MPa) as indicated by two-way ANOVA (P=<0.0001<0.05)

Regardless of GIC type, the 1% modified subgroup recorded the highest mean ± SD value of compressive strength (194.51 MPa) followed by the control (0%) subgroup mean value (180.06 MPa) meanwhile the lowest mean value was recorded with the 4% subgroup (153.47 MPa) was statistically significant as indicated by two-way ANOVA (P=<0.0001<0.05)

Table 1. Comparison of compressive strength (Mean values± SDs) between both GIC groups with different Sesame oil extract concentration

Variables		Conventional GIC				Experimental GIC				t-test
		Mean	± SDs	95% CI		Mean	± SDs	95% CI		P value
				Low	High			Low	High	
Sesame oil extract concentration	Control (0%)	191.28B	13.36	179.57	203	168.83A	8.735	161.17	176.48	0.0137 *
	1 %	230.86A	9.751	222.31	239.4	158.16AB	8.367	150.82	165.49	<0.0001*
	4 %	160.96C	4.599	156.93	164.99	145.98B	12.1	135.37	156.58	0.0322*
ANOVA	P value	<0.0001*				0.0111*				

Different letters in the same column indicating statistically significant difference (p < 0.05)

*; significant (p < 0.05)   ns; non-significant (p>0.05)

Indirect tensile strength test results (MPa):

The mean values and standard deviation of tensile strength test results (MPa) for both GIC groups with different Sesame oil extract concentration are summarized in Table 2.

Conventional GIC

It was found that the control (0%) subgroup recorded the highest mean value of tensile strength (8.916 MPa) followed by the 1% Sesame oil extract concentration modified subgroup mean value of (7.977 MPa) meanwhile the lowest mean value was recorded with 4% modified subgroup (5.531 MPa). The difference between different subgroups was statistically significant as indicated by one-way ANOVA followed by Tukey's post-hoc tests (P=<0.0001<0.05) as shown in Table 2.

Experimental GIC

It was found that the control (0%) subgroup recorded the highest mean value of tensile strength (8.892 MPa) followed by the 1% Sesame oil extract concentration modified subgroup mean value of (7.935 MPa) meanwhile the lowest mean value was recorded with a 4% modified subgroup (6.743 MPa). The difference between different subgroups was statistically non-significant as indicated by one-way ANOVA (P=0.0516>0.05) as shown in Table 2.

Conventional vs. experimental GIC

With 0% Sesame oil modification

It was noted that the conventional GIC group recorded a higher tensile strength mean value (8.916MPa) than the experimental one (8.892 MPa) and this was statistically non-significant as indicated by t-test (P=0.9416>0.05) as shown in Table 2.

With 1% Sesame oil modification

It was noted that the conventional GIC group recorded a higher tensile strength mean value (7.977 MPa) than the experimental one (7.935 MPa) and this was statistically non-significant as indicated by t-test (P=0.9484>0.05) as shown in Table 2.

With 4% Sesame oil modification

It was noted that the experimental GIC group recorded a higher tensile strength mean value (6.743 MPa) than the conventional one (5.531 MPa) and this was statistically non-significant as indicated by t-test (P=0.1423 > 0.05) as shown in Table 2.

Regardless of Sesame oil extract concentration, it was found that experimental GIC recorded statistically non-significant higher strength (7.857 MPa) than conventional one (7.475 MPa) as indicated by two-way ANOVA (P=0.2497>0.05)

Regardless of GIC type, the control (0%) subgroup recorded the highest mean value of tensile strength (8.904 MPa) followed by the 1% modified subgroup mean value (7.956 MPa) meanwhile the lowest mean value was recorded with the 4% subgroup (6.137 MPa) was statistically significant as indicated by two-way ANOVA (P=<0.0001<0.05)

Table 2. Comparison of tensile strength (Mean values± SDs) between both GIC groups with different Sesame oil extract concentration

Variables		Conventional GIC				Experimental GIC				t-test
		Mean	± SDs	95% CI		Mean	± SDs	95% CI		P value
				Low	High			Low	High	
Sesame oil extract concentration	Control (0%)	8.916A	0.18	8.76	9.07	8.892A	0.71	8.27	9.52	0.9416ns
	1 %	7.977B	0.72	7.35	8.61	7.935A	1.21	6.88	8.99	0.9484ns
	4 %	5.531C	0.45	5.13	5.93	6.743A	1.6	5.34	8.15	0.1423ns
ANOVA	P value	<0.0001*				0.0516 ns				

Different letters in the same column indicating statistically significant difference (p < 0.05)

*; significant (p < 0.05) ns; non-significant (p>0.05)

Shear bond strength test results (MPa)

The mean values and standard deviation of shear bond strength test results (MPa) for both GIC groups with different Sesame oil extract concentrations are summarized in Table 3.

Conventional GIC

It was found that the control (0%) subgroup recorded the highest mean value of shear bond strength (5.143 MPa) followed by the 1% Sesame oil extract concentration modified subgroup mean value of (4.887 MPa) meanwhile the lowest mean value was recorded with 4% modified subgroup (4.437 MPa). The difference between different subgroups was statistically non-significant as indicated by one-way ANOVA tests ($P=0.8010>0.05$) as shown in Table 3.

Experimental GIC

It was found that the control (0%) subgroup recorded the highest mean value of shear bond strength (5.802 MPa) followed by the 1% Sesame oil extract concentration modified subgroup mean value of (4.54 MPa) meanwhile the lowest mean value was recorded with 4% modified subgroup (4.532 MPa). The difference between different subgroups was statistically non-significant as indicated by one-way ANOVA ($P=0.4124>0.05$) as shown in Table 3.

Conventional vs. experimental GIC

With 0% Sesame oil modification

It was noted that the experimental GIC group recorded a higher shear bond strength mean value (5.802 MPa) than the conventional one (5.143 MPa) and this was statistically non-significant as indicated by t-test ($P=0.648>0.05$) as shown in Table 3.

With 1% Sesame oil modification

It was noted that the conventional GIC group recorded a higher shear bond strength mean value (4.887 MPa) than the experimental one (4.54 MPa) and this was statistically non-significant as indicated by t-test ($P=0.7132>0.05$) as shown in Table 3.

With 4% Sesame oil modification

It was noted that the experimental GIC group recorded a higher shear bond strength mean value (4.532 MPa) than the conventional one (4.437 MPa) and this was statistically non-significant as indicated by t-test ($P=0.9068> 0.05$) as shown in Table 3.

Regardless of Sesame oil extract concentration, it was found that experimental GIC recorded statistically non-significant higher bond strength (4.958 MPa) than conventional one (4.822 MPa) as indicated by two-way ANOVA ($P=0.8161>0.05$)

Regardless of GIC type, the control (0%) subgroup recorded the highest mean value of shear bond strength (5.473 MPa) followed by the 1% modified subgroup mean value (4.713 MPa) meanwhile the lowest mean value was recorded with 4% subgroup (4.484 MPa) was statistically non-significant as indicated by two-way ANOVA ($P=0.3854>0.05$)

Table 3. Comparison of shear bond strength (Mean values± SDs) between both GIC groups with different Sesame oil extract concentration

Variables		Conventional GIC				Experimental GIC				t-test
		Mean	± SDs	95% CI		Mean	± SDs	95% CI		P value
				Low	High			Low	High	
Sesame oil extract concentration	Control (0%)	5.143A	2.132	3.274	7.012	5.802A	2.26	3.821	7.783	0.648 ns
	1 %	4.887A	1.135	3.892	5.881	4.54A	1.688	3.06	6.02	0.7132ns
	4 %	4.437A	1.629	3.008	5.865	4.532A	0.664	3.95	5.113	0.9068ns
ANOVA	P value	0.8010 ns				0.4124 ns				

Different letters in the same column indicating statistically significant difference ($p < 0.05$)
*; significant ($p < 0.05$) ns; non-significant ($p>0.05$)

Discussion:

Since there is currently no dental material such as GIC on the market with the perfect qualities for any dental application, researchers are always looking for improvement.[15,16] This target suggests that combining various other substances with currently available dental materials may be very promising.[17]

Medicinal plants are thought to be a major source of a broad range of chemical compounds with multiple activities, in addition to being used to treat a variety of other diseases.[18] Thus, sesame oil was chosen for the current study because of its well-established health benefits in the dental field, such as its efficacy in treating dental plaque, dental caries, and halitosis in addition to its easy accessibility.[19,20]

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. Sesame oil was incorporated based on a previous study with two concentrations 1 and 4(v/v%) to determine the proper concentration that enhances the mechanical properties.[9]

The sol-gel method is a suitable and easier alternative to the traditional melt and quench method for producing GIC. Due to its relatively low synthesis temperature and ability to use thermal energy less than the temperature of oxide element crystallization through the use of liquid chemical precursors to create highly homogeneous, pure glass-like ceramic. However, a comparison of sol-gel and melt-derived glasses with similar compositions also seems to have similar structure and atomic correlations.[21]

The produced glasses were analyzed using X-ray diffraction (XRD) to determine whether they had any crystalline phases or were amorphous. XRD is a long-established technique for the non-destructive characterization of crystalline and non-crystalline materials. The conventional GIC powder sample used in this research does not exhibit any sharp peaks in the XRD analysis, showing that it is primarily an amorphous material. Additionally, the XRD analysis results of the newly synthesized glass in this study demonstrated its amorphous structure. This agreed with prior investigations, which found that the sol-gel process used to obtain a homogeneous and amorphous gel solid from a liquid sol (the sol-gel technique has not altered the glass structure).[22,23]

Infrared spectroscopy has been proven to be useful in the study of GICs as it can distinguish between metal salts formed during setting; calcium acrylate and aluminum acrylate. FTIR works based on functional groups and provides information in the form of peaks. The glass structure of the conventional GIC powder was confirmed by the results of FTIR analysis by the presence of silica hydroxyl (Si-OH) peak at 3465 cm^{-1} which is weakly observed and the presence of (Si-O) group at 1033 cm^{-1} and 718 cm^{-1} spectrum as well as silica groups (Si-O-Si and Si-O) peak at 456 cm^{-1}.[24]

Also, the glass structure of the synthesized GI C powder was confirmed by the results of FTIR analysis by the presence of well-defined bands at 455 cm^{-1} which is characteristic of Si-O-Si and Si-O that represent the main constitutional composition of GIC. While the spectral band at 1034 cm^{-1} and 718 cm^{-1} represent the (Si-O) group. peak at 3456 cm^{-1} indicates the presence of the silica hydroxyl (Si-OH) group.[24]

The compressive strength is an important property in evaluating restorative and luting materials, particularly in the process of mastication.[25] The results of the current study showed that conventional GIC has significantly higher compressive strengths when compared to the experimental one, this may be attributed to gel shrinkage that happens when liquid evaporates from pores, that have an impact on the network's strength and gel structure. Furthermore, the volume of the gel is reduced to the same extent as the volume of the evaporated liquid, and generally, changes in structure such as volume, weight, and density occur.[26]

Regardless of GIC type, the mean compressive strength of the 1% modified subgroup recorded the highest mean value followed by the control (0%) subgroup mean value meanwhile the lowest mean value was recorded with the 4% subgroup the difference in compressive strength results between subgroups might be explained on a significant amount of minerals, like calcium, are present in Sesame oil and may induce acid-base reaction to take place with a higher degree. To build polysalt bridges and cross-link into Ca polyacrylate chains, more Ca 2+ ions might be accessible. This could reinforce the GIC matrix and enhance its mechanical properties.[27, 28]

On the other hand, the lowest mean value was recorded by the 4% modified subgroup this may be because when the concentration of Sesame oil increased in the liquid up to 4% the oil lost its ability to chemically bond to glass, resulting in a polyalkonate matrix with high structural microporosity and decrease compressive strength. Also, a high concentration of oil may prevent many COOH groups from interlocking leading to slowing down the setting reaction which negatively impacts the mechanical strength.[27,29]

Direct measurement of tensile properties would be more valid but technical difficulties are encountered when applying the test method to brittle materials (which are weaker in tension than compression). The diametral tensile strength (DTS) is a property of interest to be analyzed for the clinical success of dental restorations. The diametral tensile strength tests provide simple methods for measurement of the tensile strength of brittle materials like glass ionomer cement.[25]

In this test, a compressive force is applied to disc samples across the diameter by compression plates. While the stresses in the contact regions are indeterminate, there is evidence of a compressive component that hinders the propagation of the tensile crack. The majority of the tested specimens presented a failure plane that divided the specimens into two equal parts, confirming that the data were valid.[30]

The results of the present study showed that the experimental GIC recorded non-significant higher tensile strength than the conventional one. The GIC control (0%) subgroup recorded the highest mean value of tensile strength followed by the 1% modified subgroup mean value this may be due to excessive crosslinking limiting the sliding movement of chains leading to brittleness of cement that decreases the tensile strength. meanwhile, the lowest mean value of tensile strength was recorded with a 4% subgroup this may be explained by the oil present in the GI matrix that might act as a plasticizing agent and affect the continuous setting reaction of the restorative material.[31]

Bond strength measurements were among the methods used to evaluate the effectiveness of the materials bonding to tooth structure to predict their performance in the oral environment. Bond strength test methods include; macro and micro test designs according to interfacial bonding area in tension shear and push out. A variety of tests have been developed to measure the bond strength between two materials and/or to enamel and dentine. The shear bond strength test is a popular testing method due to its simplicity, and cost efficiency, shear stresses are believed to be one of the stresses involved in the in vivo bonding failure of restoration.[32,33]

The results of the present study showed that experimental GIC recorded statistically higher bond strength than conventional one. Regardless of GIC type, the control (0%) subgroup recorded the highest mean value of shear bond strength followed by a 1% modified subgroup mean value meanwhile the lowest mean value was recorded with the 4% subgroup this could be explained by the possibility that the density of free carboxylic groups required for the chemical bond to the tooth structure is affected by the addition of sesame oil to the liquid. The presence of Ca ions in sesame oil may partially deplete some of the carboxylic acids in polysalt bridge formation.[34,35]

Conclusions:

Based on the findings of this study, and within the limitation of the in vitro investigation, it can be concluded that Sesame oil enhanced the compressive strength at low concentration while it showed a weakening effect at high concentration. Regarding diametral tensile strength both concentrations exhibited a determinal influence for both GIC formulations, shear bond strength was affected non-significantly.

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