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Evaluation and Comparison of Physical Properties of Essential Oil Modified Glass Ionomer Cement: An In Vitro Study

Dr. Ankith Mohan[1] Post Graduate, Dr. Ankur Jain[2] Prof. and HOD, Dr. M Krishna Sagar[3] Reader, Dr. Ayushi Thakur[4] Post Graduate, Dr. Aruna Rethan[5] Post Graduate, Dr Ali Khan[6] Senior Lecturer.

[1,2,3,4,5,6] **Department of Pediatric and Preventive Dentistry, People's Dental Academy, Bhopal**

Corresponding author **E-mail: -** ankith567@gmail.com

ORCID ID- 0009-0000-6625-4896

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ABSTRACT

Background: - Glass ionomer cements (GICs) have many applications in the oral cavity of primary teeth.This is due to their favourable characteristic properties like chemical adhesion to enamel and dentin, fluoride release, coefficient of thermal expansion and modulus of elasticity close to dentin and biocompatibility to pulp**.**However it possesses certain short comings such as high solubility, low flexural strength, low fracture toughness and also after a period of time from the completion of a dental restoration, biofilm formation occurs on the GIC surface with subsequent degradation of the material, which limits its clinical performance with time. **Aim and objectve** is to Evaluate and compare the physical properties of essential oil modified glass ionomer cements. **Materials and Methods**. Extracted premolar indicated for orthodontics purpose, Glass ionomer cement (P&L), Grape seed oil 3%, Sesame seed Oil 5%, Cinnamon oil 5%, were obtained**.** Conventional glass ionomer cement and the essential oils were incorporated into the liquid component in specific ratios and kept on the magnetic stirrer for 24 hours for obtaining a homogenous mix. The utilization of these liquid will produce three different groups as follows Group I– Conventional GIC (control group),Group II – GIC with 5% sesame seed oil, Group III – GIC with 3% grape seed oil, Group IV- GIC with 5% cinnamon oil. A total number of 100 specimens were used to assess the compressive strength, shear bond strength, diametral tensile strength, surface microhardness and surface roughness. **Result-** It was observed that 5% sesame oil modified GIC had the highest mean of compressive strength, shear bond strength, diametral tensile strength, surface microhardness. However, on assessing the surface roughness 3% Grapeseed oil modified had the lowest mean. **Conclusion** The result of the present study shows that the addition of 5% sesame seed oil has shown superior physical properties as compared to the other essential oil put forth in the study, hence this modification can in done in glass ionomer cement while restoring the tooth

KEY WORDS: - Glass ionomer cement, Grape seed oil ,Sesame seed Oil, Cinnamon oil

INTRODUCTION

The function and integrity of teeth can be destroyed by caries or trauma. After removing the caries or curing the trauma, dental restorative cements are required to restore the missing tooth structure. Dental restorations are placed in a rather harsh oral environment. They are subjected to thermal shock, chemical corrosion and repeating masticatory forces.[1]

The ideal dental restorative cements should also be bioactive, which could increase their bonding to teeth and close the gaps between them by forming an appetite layer. GIC is one of the most widely used dental restorative cements nowadays. Conventional GIC is based on the reaction between polyacrylic acid (PAA) and glass powder containing silica, calcium, alumina, and fluoride. However conventional GICs possess certain short comings such as susceptibility to dehydration, high solubility,[2,3] low flexural strength, low fracture toughness, low wear resistance, brittleness, water sensitivity and also after a period of time from the completion of a dental restoration, biofilm formation occurs on the GIC surface with subsequent degradation of the material, which limits clinical performance over time.[4]

In order to overcome these disadvantages, studies have been done to modify either the glass powder or polyelectrolyte.[5] Various studies have combined antimicrobial agents with restorative materials (especially with GIC) in an attempt to reduce the formation of biofilm and prevent the occurrence of secondary caries, thus improving antimicrobial activity while enhancing clinical efficacy.

One such modification is the use of oils such as grape seed oil, cinnamon oil, sesame seed oil that influence the physical properties of conventional glass ionomer cement These oils are obtained naturally and has numerous biological and dental uses, also the anti-inflammatory, antioxidant, and antibacterial properties can lessen dentine degradation by creating crosslinks within the collagenous structures, which in turn strengthens them.[6]

The present study aims to find out more alternative to develop GIC with enhanced properties, by incorporating different oils as additives along with the liquid in conventional GIC. The microhardness, surface roughness, diametric tensile strength, shear bond strength and compressive strength of GICs are evaluated in this study.

MATERIALS AND METHODS

Non carious extracted premolars indicated for orthodontics purpose were obtained from the Department of Oral & Maxillofacial surgery, Peoples Dental Academy Bhopal. [FIGURE-1]

(A) Inclusion Criteria:

- Premolars indicated for orthodontic extraction.

(B) Exclusion Criteria:

- The teeth with any anomalies such as hypoplasia, fluorosis etc, were excluded

Materials: -

1. Glass ionomer cement (P&L) (GC Gold label) [FIGURE-2]

2. Grape seed oil (Tattavalogy pure grape seed oil) [FIGURE-3]

3. Seasme seed Oil (Sprig pure sesame seed oil) [FIGURE-4]

4. Cinnamon oil (Khadi earth cinnamon oil) [FIGURE-5]

Armamentarium: -

For recording mechanical properties

1. Profilometer to access surface roughness

2. Vicker's hardness tester machine to access micro hardness

3. Universal testing machine for diametric tensile strength and compressive strength

Miscellaneous

1. Split Teflon mould 5nos (For preparing the specimen)

2. Extracted premolar teeth for shear bond strength test

3. Kidney tray

4. Cotton roll

5. Tweezer

6. Green cloth

7. Mouth mirror

Study Variables: Dependent

1. Surface roughness

2. Micro hardness

3. Compressive strength

4. Shear bond strength

5. Diametric tensile strength

Independent

1. Conventional GIC

2. GIC +3% GRAPE SEED OIL

3. GIC+ 5% SEASME SEED OIL

4. GIC+ 5% CINNAMON OIL

Sample Size:

• The sample size was calculated using G*Power 3.1.9.7 software.

• Based on the following criteria; effect size- 1.9 (according to previous research by Aref NS et al.[9]in 2021, α probability error- 0.05, power (1-β error probability)- 0.80 and number of groups- 4, the minimum required sample size was 12 i.e., 03 in each group.

• However, it was proposed to include 5 samples for each test. Hence a total of 100 specimen (25 specimen for each parameter) was taken as final sample size.

Total of 100 specimen collected were divide into 4 groups of 25 each:

1. Group I– Conventional GIC (Control Group)

2. Group II – GIC with 5% Sesame Seed Oil

3. Group III – GIC with 3% Grape Seed Oil

4. Group IV- GIC with 5% Cinnamon Oil

DATA COLLECTION AND PROCEDURE

Conventional glass ionomer cement and the essential oils were used in the study for preparing the required specimen. The essential oils were incorporated into the liquid component in specific ratios and kept on the magnetic stirrer for 24 hours for obtaining a homogenous mix.

The utilization of these liquid produced three different groups as mentioned above Hence, a total no. of 100 specimens were taken to assess the compressive strength, shear bond strength, diametral tensile strength, surface microhardness and surface roughness.

Powder and liquid of each formulation were mixed and specimens are prepared with split Teflon on the basis of specifications assigned for each test. All specimens will keep in deionized water at 37°C for 24 hours before testing.

1.Compressive Strength: - Cylindrical specimens 4 mm diameter and 6 mm length

2. Diametral Tensile Strength (DTS): - Cylindrical specimens 4 mm diameter and 6 mm length

3. Surface Microhardness: - Disc-shaped specimen of 6 mm × 3 mm.

4. Shear Bond Strength: - extracted premolars are used for preparing the specimens, a split Teflon mould 4 mm × 4 mm is used for bonding GIC to the dentin surface

5. Surface Roughness (Ra): - Disc-shaped specimen of dimensions 8 mm × 2 mm

So, out of 25 samples in a group, 5 samples each have gone for compressive strength test, diametric tensile strength, microhardness, surface roughness, shear bond strength.

FIGURE NO. 1: EXTRACTED PREMOLAR TOOTH

FIGURE NO.2:

GLASS IONOMER CEMENT

FIGURE NO. 3:
GRAPE SEED OIL

FIGURE NO. 4:
SEASME SEED OIL

FIGURE NO.5:

CINNAMON OIL

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS (Statistical Package for Social Sciences) 21.0 version, IBM, Chicago. The data was analysed for probability distribution using Kolmogorov-Smirnov test. The descriptive statistics was performed. The inter-group comparison of continuous variables was done using One-way ANOVA/. Post -Hoc analysis was done using Tukey's HSD test. P value< 0.05 was considered significant.

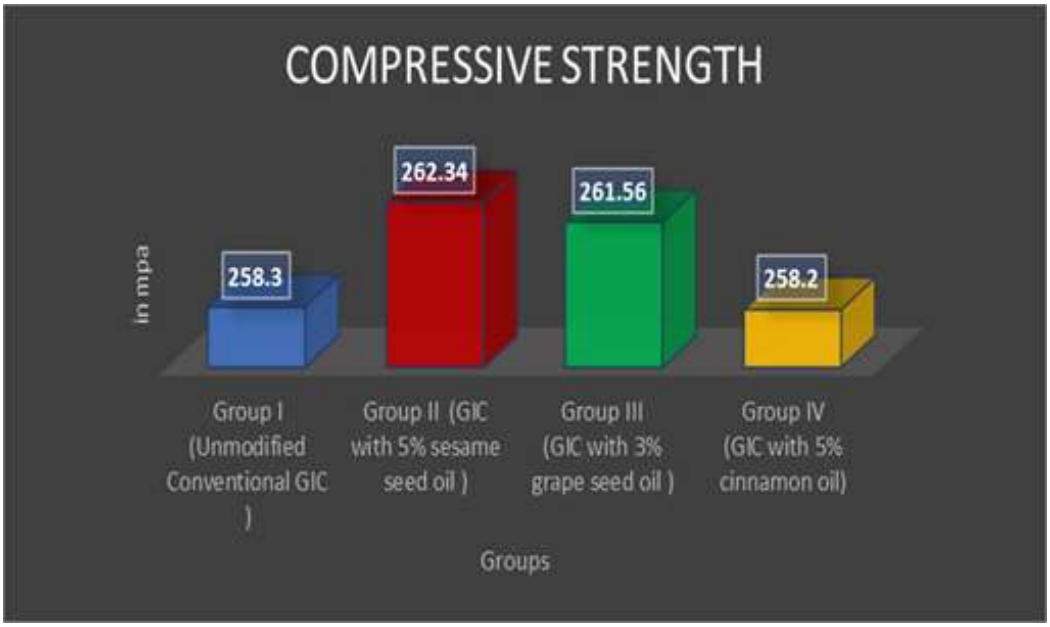
RESULTS

COMPRESSIVE STRENGTH.: -

For compressive strength, it was observed that 5% sesame oil modified GIC had the highest mean (262.34 ± 4.15 MPa) followed by 3% Grapeseed oil modified GIC (261.56±3.1 MPa) and unmodified GIC (258.30 ± 5.41 MPa) while 5% cinnamon modified GIC cement had the lowest (258.20 ± 6.6 MPa)(Table-1). ANOVA test indicated a significant difference among groups (p=0.036). Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV. On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups

Group I– Conventional GIC (control group) in MPa (Mean ± SD)	**Group II – GIC with 5% sesame seed oil in MPa (Mean ± SD)**	**Group III – GIC with 3% grape seed oil in MPa (Mean ± SD)**	**Group IV- GIC with 5% cinnamon oil in MPa (Mean ± SD)**	**P value (ANOVA)**
258.30 ± 5.41	**262.34 ± 4.15**	**261.56±3.1**	**258.20 ± 6.6**	**0.036**

Table-1 shows the compressive strength of different formulations of Modified glass ionomer cement

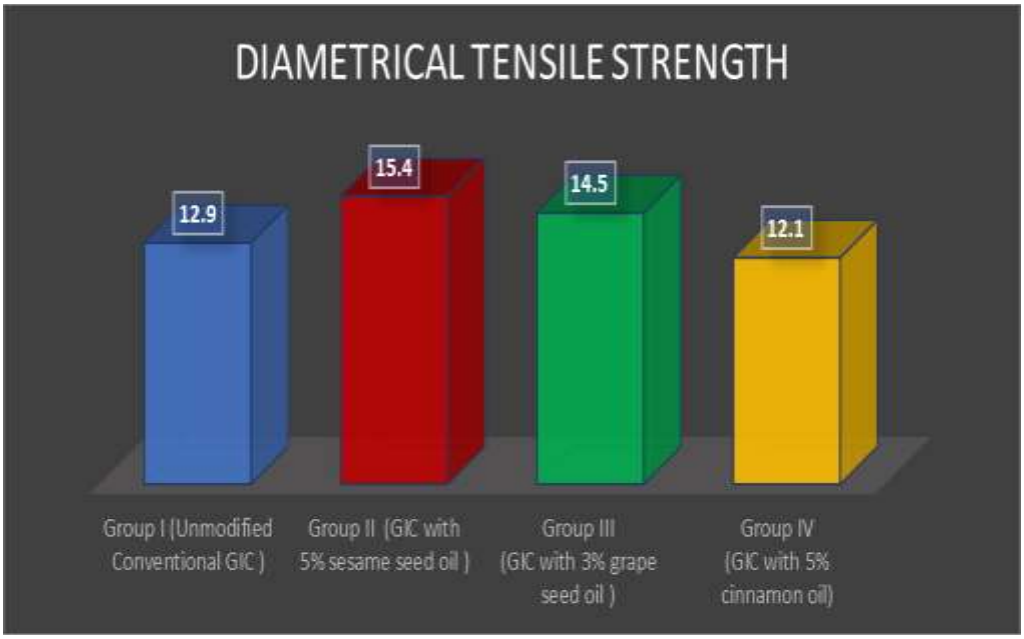


DIAMETRAL TENSILE STRENGTH (DTS): -.

For diametrical tensile strength, it was observed that 5% sesame oil modified GIC had the highest mean (15.4 ± 3.10 MPa) followed by 3% Grapeseed oil modified GIC (14.5 ± 2.54 MPa) and unmodified GIC (12.9 ± 2.53 MPa) while the 5% cinnamon modified GIC cement had the lowest (12.10 ± 2.60 MPa) (Table-2). ANOVA test indicated a significant difference among groups (p=0.041). Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV. On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups.

Group I Conventional GIC (control group) in MPa	**Group II GIC with 5% sesame seed oil in MPa**	**Group III GIC with 3% grape seed oil in MPa**	**Group IV GIC with 5% cinnamon oil in MPa**	**P value**
12.9 ± 2.53	**15.4 ± 3.10**	**14.5 ± 2.54**	**12.10 ± 2.60**	**0.041**

Table-2 shows the Diametral tensile strength of different formulations of Modified glass ionomer cement

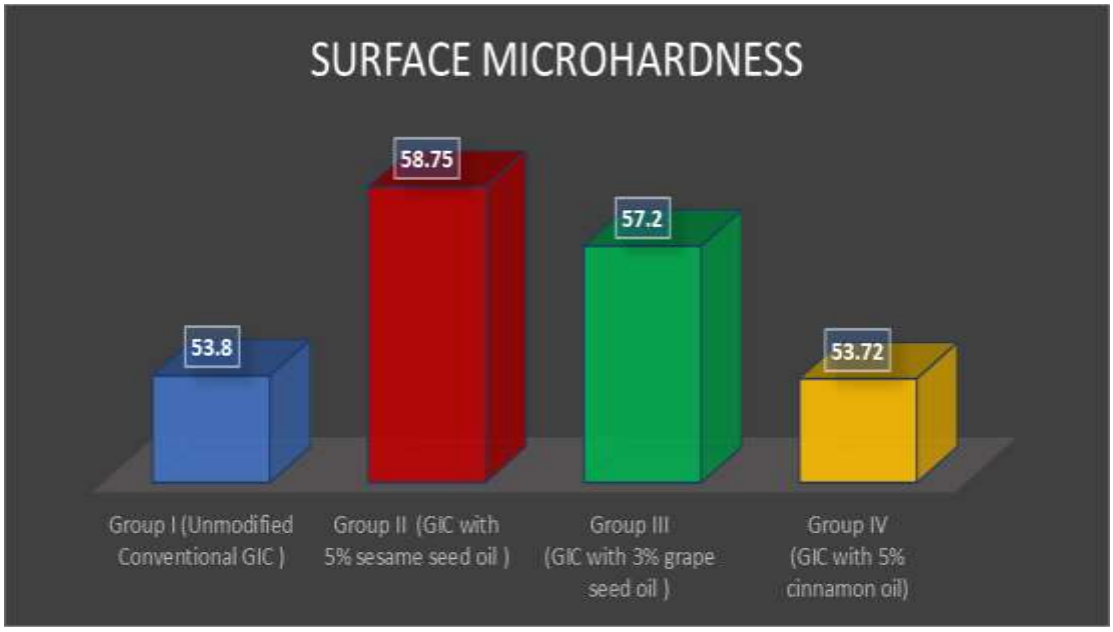


SURFACE MICROHARDNESS: -

For surface microhardness, it was observed that 5% sesame oil modified GIC had the highest mean (58.75± 2.5 kg/mm^2) followed by 3% Grapeseed oil modified GIC (57.20 ± 3.45 kg/mm^2) and unmodified GIC (53.80± 3.22 kg/mm^2) while the 5% cinnamon modified GIC cement had the lowest (53.72 ± 3.10 kg/mm^2) (Table-3). ANOVA test indicated a significant difference among groups (p=0.029). Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV. On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups.

Group I– Conventional GIC (control group) in kg/mm^2	**Group II – GIC with 5% sesame seed oil in kg/mm^2**	**Group III – GIC with 3% grape seed oil in kg/mm^2**	**Group IV- GIC with 5% cinnamon oil in kg/mm^2**	**P value (ANOVA)**
53.80± 3.22	**58.75± 2.5**	**57.20 ± 3.45**	**53.72 ± 3.10**	**0.029**

Table-3 shows the surface microhardness of different formulations of Modified glass ionomer cement

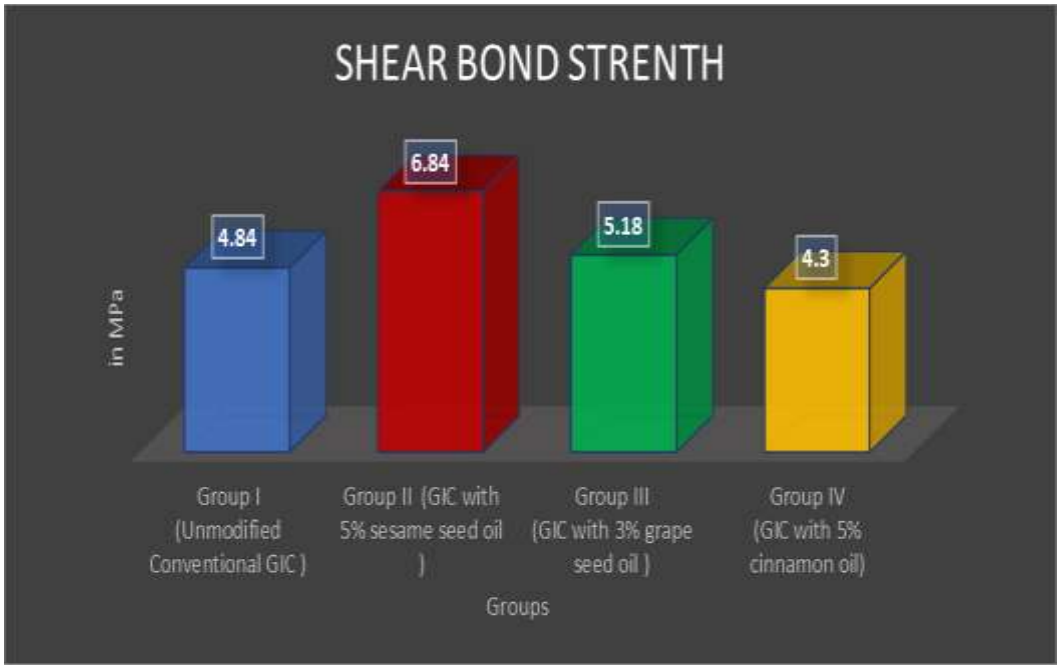


SHEAR BOND STRENGTH: -

For shear bond strength, it was observed that 5% sesame oil modified GIC had the highest mean (6.70 ± 1.02 MPa) followed by 3% Grapeseed oil modified GIC (5.28 ± 1.02MPa) and unmodified GIC (4.84 ± 1.21 MPa) while the 5% cinnamon modified GIC cement had the lowest (4.30±1.10 MPa) (Table-4). ANOVA test indicated a significant difference among groups (p=0.010). Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV . On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups.

Group I– Conventional GIC (control group) in MPa	**Group II – GIC with 5% sesame seed oil in MPa**	**Group III – GIC with 3% grape seed oil in MPa**	**Group IV- GIC with 5% cinnamon oil in MPa**	**P value (ANOVA)**
4.84 ± 1.21	**6.70 ± 1.02**	**5.28 ±0.62**	**4.30±1.10**	**0.010**

Table-4 shows the Shear bond strength of different formulations of Modified glass ionomer cement



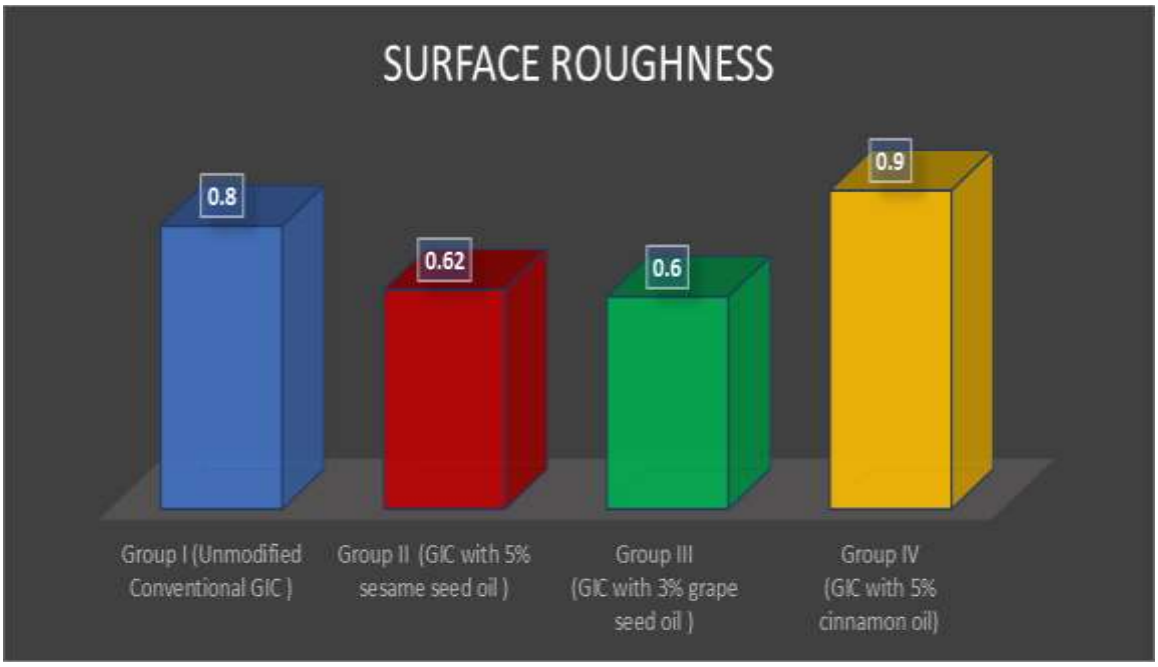
SURFACE ROUGHNESS: -

For surface roughness, it was observed that 3% Grapeseed oil modified had the lowest mean (0.60±0.06 μm) followed by 5% sesame oil modified GIC (0.62 ± 0.04 μm) and unmodified

GIC (0.8 ± 0.07 μm) while the 5% cinnamon modified GIC cement had the highest (0.9 ± 0.05 μm) (Table-5). ANOVA test indicated a non-significant difference among groups (p=0.540).

Group I– Conventional GIC (control group)	**Group II – GIC with 5% sesame seed oil**	**Group III – GIC with 3% grape seed oil**	**Group IV- GIC with 5% cinnamon oil**	**P value**
0.8 ± 0.07	**0.62 ± 0.04**	**0.60±0.06**	**0.9 ± 0.05**	**0.540**

Table-5 shows the Surface roughness of different formulations of Modified glass ionomer cement



DISCUSSION

Glass ionomer cement has gained wide acceptance in minimal invasive dentistry mainly due to its ease of handling characteristics, chemical bonding to tooth structure, and fluoride release. In minimally invasive approaches, the possibility of microorganisms remaining in the cavity increases the risk of restoration failure due to secondary caries. Secondary and initial caries have similar microbiology. Streptococci, Lactobacilli and Actinomyces are involved in the early stages of bacterial invasion in caries development. *Streptococcus mutans* is the primary bacterium responsible for caries formation. *Lactobacillus acidophilus* is responsible for the progression of caries and the formation of secondary caries.[7] *Actinomyces naselundii* is associated with root caries and can invade dentinal tubules.

The use of materials with antibacterial or bactericidal effects, especially in minimally invasive approaches, will provide additional treatment by suppressing residual infection and increasing the life of the restored tooth.[7] Among the surveyed antimicrobials used in dentistry, essential oils (EOs) have been considered as promising molecules. EOs are volatile aromatic liquids and complex plant materials known for their medicinal properties, such as analgesia, sedation, anti-inflammatory, spasmolytic and local anesthetic activities. In view of this, the present study evaluated the physical properties following addition of 5% sesame seed oil, 3% grape seed oil and 5% cinnamon oil in glass ionomer cement.

Compressive Strength.: -

The findings of compressive strength results in the present study were in agreement with the findings of Aref NS (2021),[8] ArefNS and Abdallah RM (2021).[9] In contrast, Palmer et al.[10]reported decrease in compressive strength with increasing the additives ratio to the parent cement. Similarly, consistent results were seen in the study done by Xie et al. [11] where quaternary ammonium compound was added to GIC as an antibacterial agent. The finding could be attributed to the composition of sesame oil. It contains considerable amount of minerals including calcium which may induce a higher degree of the acid base reaction. More Ca2+ ion may be available for polysalt bridge formation and cross-linking into Ca polyacrylate chains, in that way reinforcing the GIC matrix, and increasing the mechanical properties. Also, normally during gelation stage of the reaction, the carboxylate groups of the polyacrylic acid polymer chains become charged, repel each other, uncoil and seemingly retain a more linear pattern.[12]

Whereas as grape seed oil interferes with the acid base reaction and prevent some carboxylic groups from participating in the reaction. They are supposed to hinder the acid attack to the glass powder and the leaching of ions from the glass. Also, the oil itself may act as an adhesive penetrating the pores within the formed matrix and thus promoting cohesion and developing a stronger matrix. As well, the sufficient number of the unreacted carboxylic groups may contribute to appropriate bonding with the tooth structure.[13]

The decrease in compressive strength by Cinnamon oil could be due to the failure of chemical bonding of essential oils to both the glass and the polyalkenoate matrix, the micro-porosity of the GIC might have increased thus reducing the compressive strength.[14] Another possible reason is that the slowing down of the setting reaction within the matrix of glass ionomer due to lower carboxylic group density within the reaction medium might have adversely affected the cross linking of polyanions within the GIC matrix leading to lower strength. [15]

Diametral Tensile Strength (DTS):

Aref NS in (2021)[8] found significantly increased diametral tensile strength (MPa) with modification of GIC with sesame oil with the highest mean belonging to 5 (v/v%) sesame oil-modified GICs (5.9 ± 0.53) from the unmodified GIC.

Till date, no other study compared the diametrical tensile strength of Grape seed and cinnamon oil modified GIC. Our findings could be attributed to the concentration of cinnamon and grapeseed oil which might have undergone oxidation, thus increasing the carboxylic (COO^-) group and H^+ density leading to further cross linking of the glass ionomer matrix. Such crosslinking might have neutralized the weakening effect induced by the addition of the essential oil which has possibly reduced to certain extent the cohesive forces within the cement.[16]

Surface Microhardness: -

Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV. On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups.

Rationally, the surface microhardness results should be consistent with the results of both compressive strength and diametral tensile strength. The ability of sesame oil to increase the degree of cross-linking and interlocking within the cement matrix may offer a stronger and harder cement with more resistance to scratching.[8] Additionally, sesame oil is an excellent source of phosphorous, iron, magnesium calcium, manganese, copper and zinc, and this mineral combination may be a complementary aspect while illuminating the oil potentiality to enhance the surface microhardness of the cement.[17] This reinforcing minerals mixture can heighten the wear resistance as well as diminishing brittleness of the cement. The results are in harmony with the findings by Moshaverinia et al.[18], who concluded that nano bioactive ceramics improved the mechanical properties of GIC and its bond strength to dentin. Alternatively, the results are inconsistent with another study which revealed that the incorporation of bioactive glass in the glass ionomer cement deteriorated its mechanical properties.[19]

Shear Bond Strength: -

Tukey test revealed that Group II and III were significantly different from the unmodified GIC and Group IV. On the other hand, no significant difference was detected between Group I and IV sesame oil-modified groups.

The addition of sesame oil to the liquid may influence the density of free carboxylic groups necessary for the chemical bond to the tooth structure. The presence of Ca ions in sesame oil may exhaust some of the carboxylic acid in polysalt bridge formation. In opposition, another

factor may elucidate the increase in the bond strength values. The phosphrous and calcium content of sesame oil may form chemical bond with calcium of the tooth structure rendering more adhesion. [8,9]

Surface Roughness: -

It was claimed that viscous liquid of the conventional GIC may be a main cause of difficult manipulation and development of porosity during hand mixing. Additionally, it was reported that hand mixed cement has larger bubbles than encapsulated forms. This porosity may be one of the causes for higher surface roughness value of the conventional cement. The findings of the surface roughness support the assumption that sesame oil or its ingredients may be responsible for sealing the pores within the cement in both tested concentrations with an enhancement of the packing density.[20]

For surface roughness, several factors are known to influence the surface roughness. Among these factors, the particle size and distribution of the additive within the parent material. Furthermore, the hand mixing of the GIC used in the study is an important factor to be considered since it increases the chance of developing pores within the mixed cement.[21] The ability of the oil form of the GS to seal the pores within the matrix producing more cohesive structure may explain the lower surface roughness values of the oil modified GIC groups rather than the control and the essential oil modified ones which possess lack of sealing capacity. This finding is consistent with the compressive strength results and validation.[22]

On assessment of the current study evaluating the physical properties of GIC with essential oil, it has been validated that the GIC with addition of 5% sesame seed oil has shown the superior properties.

CONCLUSION

- The present study, has shown that the addition of 5% sesame seed oil has shown superior physical properties as compared to the other essential oil put forth in the study.
- The sesame seed oil contains considerable amount of minerals including calcium which may induce a higher degree of the acid base reaction. Sufficient Ca2+ ions might be readily available for the creation of polysalt bridges and for cross-linking into Ca polyacrylate chains, strengthening the GIC matrix and improving its mechanical qualities.
- The compressive strength, diametric tensile strength, surface microhardness, shear bond strength, were superior for the GIC modified with 5%seasme seed oil followed by GIC modified with 3% grape seed oil.

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