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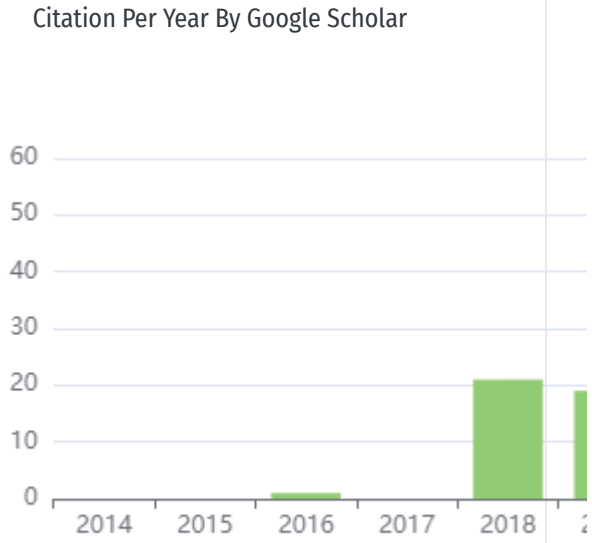

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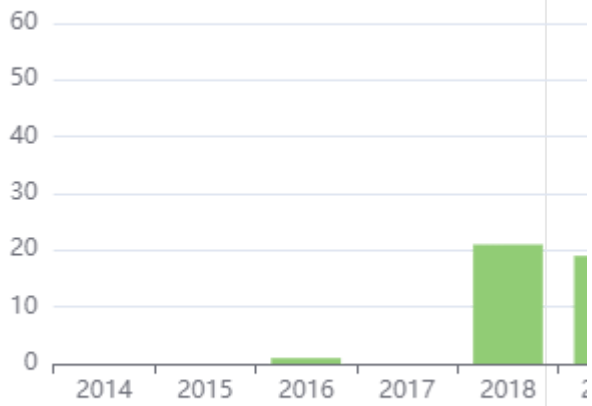

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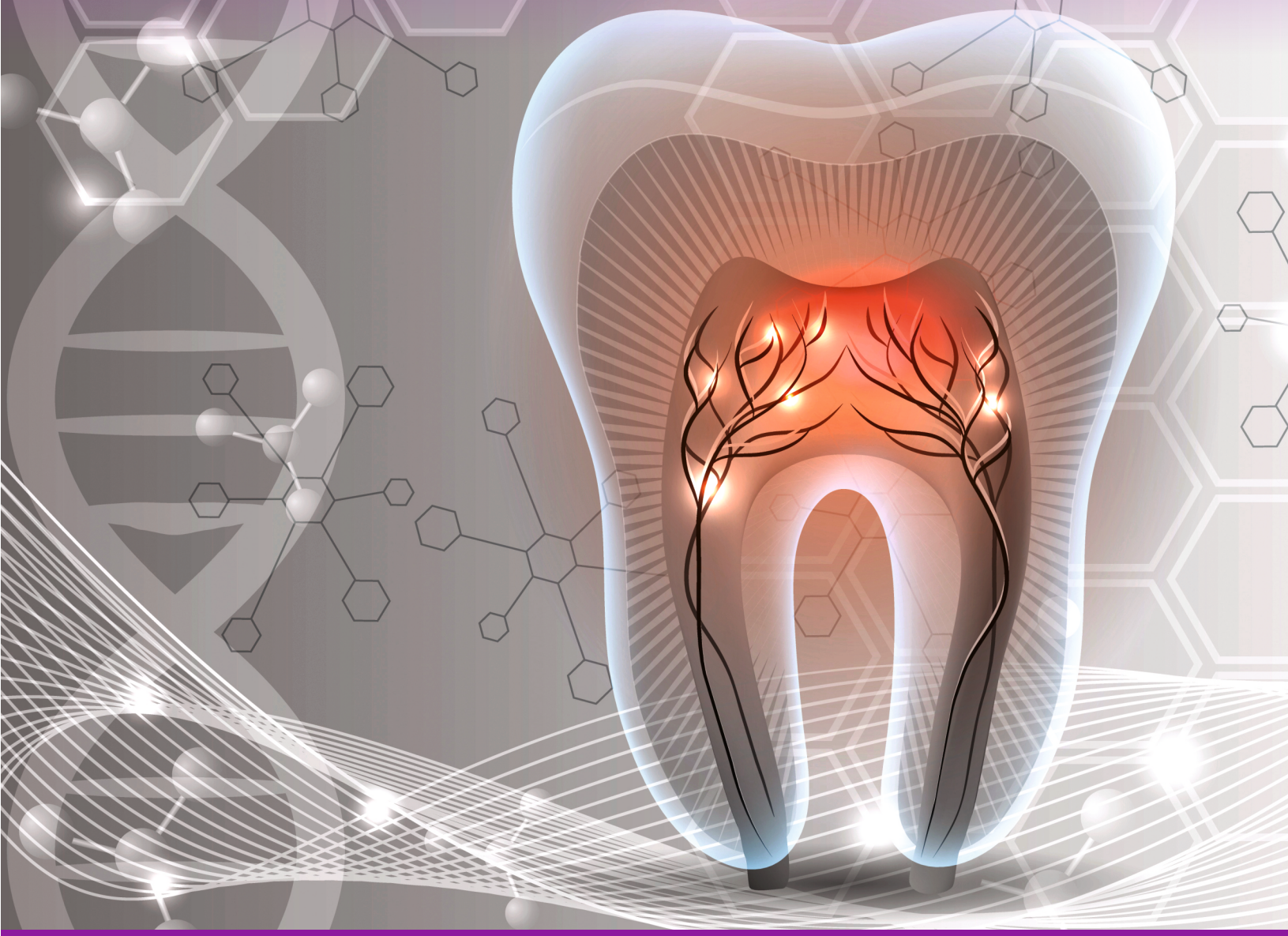

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Original Article

In Vitro Evaluation of the Compressive Strength of Glass Ionomer Cement Modified with Propolis in Different Proportions

Advita Azalia, Deviyanti Pratiwi, Akhmad Endang Zainal Hasan[1], Rosalina Tjandrawinata, Eddy Eddy

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Abstract

Background: Antibacterial additives are frequently added in an effort to enhance the antibacterial properties of glass ionomer cement (GIC). GIC modified with ethanolic extract of propolis (EEP) has been proven to improve GIC's antibacterial properties, but this modification is suspected to have detrimental impacts on its compressive strength. **Objectives:** To evaluate the compressive strength of GIC incorporated with different proportions of propolis extracts from *Trigona* spp. from Garut, Indonesia. **Methods:** This experimental *in vitro* laboratory study comsisted of 20 cylindrical glass ionomer specimens divided into four groups according to the proportions of propolis added to the GIC liquid: Group A: conventional GIC (control), Group B: 25% EEP added (% w/w), Group C: 30% EEP added (% w/w), and Group D: 35% EEP added (% w/w). A universal testing machine was used to assess compressive strength after the samples were immersed in artificial saliva and incubated for 24 h. Data were analyzed with one-way analysis of variance and Tukey's test ($P < 0.05$). **Results:** The addition of EEP decreased the compressive strength of the GIC liner. Mean compressive strength values were 118.06 ± 24.1 MPa (Group A), 103.17 ± 10.26 MPa (Group B), 79.18 ± 9.99 MPa (Group C), and 77.03 ± 6.13 MPa (Group D). In comparison to the control group, a nonsignificant difference was observed when 25% EEP was added ($P > 0.05$), whereas both 30% EEP and 35% EEP resulted in significant decreases in compressive strength ($P < 0.05$). **Conclusion:** GIC modified with 25% EEP might be a promising restorative material for cavity linings.

Keywords: *Compressive strength, ethanolic extracts of propolis, glass ionomer cement, Trigona spp*

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Background

Dental caries remains one of the most common oral diseases worldwide.[1] Currently, minimally invasive dentistry is the approach used in the treatment of deep caries. This treatment involves partial caries removal followed by the application of an adhesive restorative material.[2] Resin-based materials are often used; however, these pose the issue of polymerization shrinkage, which leads to microleakage and postoperative sensitivity.[3,4] Therefore, liners are added to protect dental pulp and to minimize the risks of polymerization shrinkage.[5]

Because of its biocompatibility, adherence to tooth structures, and fluoride release, glass ionomer

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cement (GIC) is among the commonly used dental materials.[6] Its most distinguishing factor is its ability to release fluoride, but its anticariogenic effectivity is still debatable. Several clinical studies have provided inconsistent results regarding the ability of the fluoride released to inhibit the incidence of secondary caries.[7] GIC releases 10 ppm of fluoride within the first 48 hours after its application. This level of fluoride release is considered low and less efficacious for providing the desired antibacterial effect.[8]

Liners with effective antibacterial properties are advantageous because they can overcome problems related to persistent cariogenic microorganisms found after partial caries removal. Additional antibacterial properties could help reduce the number of living microorganisms, thereby preventing the development of caries and pulpal infection, which are major causes of patient discomfort.[9,10] Thus, antibacterial additives capable of improving the antibacterial properties of GIC without adversely affecting its mechanical properties are needed.

Propolis is a natural resin material produced by honey bees of the *Trigona* genus, commonly found across the islands of Java, Sumatra, Maluku, and Kalimantan.[11,12] Propolis contains bioactive components with various pharmacological effects, including antibacterial, antifungal, antiviral, antiparasitic, anti-inflammatory, antiproliferative, antioxidant, and anticancer properties. These properties, along with its nontoxic nature and minimal allergic reactions, have made propolis a popular biomaterial in medicine. In dentistry, propolis has been a prominent ingredient in commercial antibacterial toothpaste and mouthwash.[13]

Several studies have concluded that GIC modified with an ethanolic extract of propolis (EEP) has improved antibacterial properties against *Streptococcus mutans* and *Lactobacillus acidophilus*.[14-16] At the same time, it is known that propolis additives may compromise the mechanical properties of GIC.[15,17] Compressive strength is of utmost importance because sufficient strength is needed to withstand the mastication forces within the oral cavity.[18] Ideally, materials used as liners are required to have compressive strengths equal to that of dentin or the permanent restoration placed over it.[19]

It has been proven that GIC with a proportion of 50% EEP can eliminate a number of oral microbiomes, whereas proportions under 25% EEP are less effective. However, greater concentrations of EEP result in GIC with lower compressive strength.[14,15] There are limited studies evaluating the effect of EEP on the compressive strength of GIC, and the effect of EEP from *Trigona* spp. of Garut, Indonesia on GIC has not been evaluated. Taking into account the description above, the current study aimed to evaluate the effect of propolis extracts from Garut, Indonesia in proportions of 25%, 30%, and 35% on the compressive strength of GIC liners.

Materials and Methods

This *in vitro* experiment was conducted from November to December 2022 at the biochemistry laboratory, IPB University, Bogor for extract formulation and the DMTCore Laboratory, Universitas Trisakti, Jakarta for sample testing. Raw propolis collected from species of *Trigona* originating in Garut, Indonesia was cut into small pieces and ground into powder. The propolis powder was then extracted by maceration using 70% ethanol for 48 h at 30°C. The extract was filtered using filter paper (No. 41, Whatman, Buckinghamshire, UK), and the solvent was evaporated using a dehumidifier for 24 h at 45°C. A total of 0.5 g of propolis extract was dissolved in 90% ethanol to a volume of 10 mL. Then, 5.5 g of maltodextrin (QinHuangDao LiHua Starch Co., Ltd, Hebei, China) was added, and the solution was stirred using ultrasonication for 20 min.

GC Gold Label Luting and Lining Cement (GC Corporation, Tokyo, Japan) were used in the current study. Modifications were made by incorporating EEP with GIC liquid at 25% w/w, 30% w/w, and 35% w/w. The number of samples was determined using the Lemeshow formula. A total of 20 samples were made and divided into four groups:

- Group A: GIC (GC Corporation)
- Group B: GIC modified with EEP at 25% w/w
- Group C: GIC modified with EEP at 30% w/w
- Group D: GIC modified with EEP at 35% w/w

The GIC powder, GIC liquid, and EEP paste were measured on an analytical balance (FS-AR210, Fujitsu, Tokyo, Japan) and mixed according to the manufacturer's instructions using a paper pad and plastic spatula. The mixture was placed carefully into cylindrical molds using a plastic filling. The surface was covered with a mylar strip, glass plate, and 2 kg weight. After the setting reaction was completed, the sample was removed from the mold. Samples made according to the inclusion criteria with flat, smooth, and unfractured surfaces were stored in a plastic container fully immersed in artificial saliva with a pH of 7 and placed in an incubator (LIB-080M, LabTech, Namyangju, South Korea) at 37°C for 24 h.

Samples were prepared using cylindrical molds measuring 6 mm in height and 4 mm in diameter. After 24 h, the samples were dried, and the diameter and height were measured using a digital caliper (Krisbow, Surabaya, Indonesia). The compressive strength was measured using a universal testing machine (AGS-X 5kN, Shimadzu, Tokyo, Japan). The sample was placed in a vertical position, and a force load was applied along the long axis of the sample at a crosshead speed of 1 mm/min.[20]

The compressive strength was computed using the equation:

$$Cs = \frac{4F}{\pi d^2},$$

where *Cs* is the compressive strength (MPa), *F* is the fracture load (N), and *d* is the diameter of the specimen (mm).[21]

Statistical analysis

Statistical tests were performed using statistical package for the social sciences (IBM SPSS Statistics for Macintosh, Version 29.0. Armonk, NY: IBM Corp). Data from the compressive strength test were tested for normality using the Shapiro–Wilk test, and homogeneity was tested using Levene's test. Normally distributed ($P > 0.05$) and homogeneous ($P > 0.05$) data were further analyzed using one-way analysis of variance followed by Tukey's *post hoc* test with a significance level of $P < 0.05$.

Results

Qualitative phytochemical screening was done to detect the presence of secondary metabolites in the propolis extract from *Trigona* spp. of Garut, Indonesia. The results showed that the propolis extract used in the present study acquired five secondary metabolites, namely, terpenoids, flavonoids, alkaloids, steroids, and tannins [Table 1].

The means and standard deviations of the groups' compressive strength are displayed in Figure 1. It can be inferred that the compressive strength of GIC decreased when EEP was added. The data in this study were normally distributed and homogenous. The one-way analysis of variance test obtained a value of $P < 0.001$, which indicated a significant difference between the sample groups tested. Tukey's *post hoc* test revealed a statistically nonsignificant difference between Group B (25% EEP) and Group A (0% EEP, control) $P = 0.385$. In contrast, Group C (30% EEP) and Group D (35% EEP) had significantly lower compressive strengths compared to Group A (unmodified GIC) ($P < 0.05$).

Table 1: Phytochemical test results of EEP from *Trigona* spp

Extract	Phytochemical test	Result	Test Method
Propolis *Trigona* spp.	Terpenoids	+	Qualitative
	Flavonoids	+	
	Alkaloids	+	
	Steroids	+	
	Tannins	+	

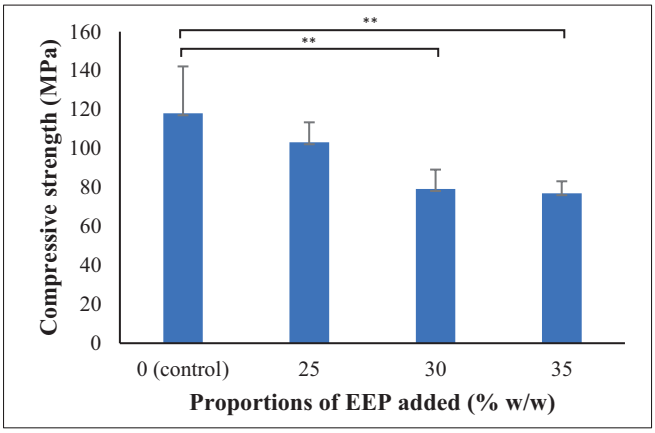

Figure 1: Compressive strength (MPa) results of EEP-modified GIC. $^{**}P < 0.01$

Discussion

EEP is recognized for its antibacterial nature, which is attributed to various natural components, namely phenolic acids, flavonoids, and terpenes.[22] Similar compounds have been found in the EEP from the *Trigona* species of Garut, Indonesia, which was used in this study.

The overall result of this study indicates that EEP-modified GIC has reduced compressive strength compared to unmodified GIC. This result is consistent with the findings of Subramaniam *et al.*,[17] who showed that the addition of 1% w/v propolis significantly reduced the compressive strength of GIC. In addition, this study found that greater proportions of EEP added to GIC resulted in lower compressive strength. The 25% EEP group showed higher compressive strength compared to the 30% and 35% EEP groups. Although GIC modified with 25% EEP is not as effective as GIC with 50% EEP, previous studies have shown that the addition of 25% EEP still has an impact on the antibacterial property of GIC.[14]

Interestingly, the decrease in the compressive strength of GIC with 25% EEP was statistically nonsignificant compared to unmodified GIC. Several studies have concluded that the addition of antimicrobial agents does not significantly affect the compressive strength

of GIC in certain concentrations. Singer *et al.*[23] added a mixture of *Salvadora persica*, *Ficus carcia*, and *Olea europaea* plant extracts to GIC. They concluded that plant extract to water ratios of 1:2 and 1:1 had no significant effects on the compressive strength of GIC.[23] Garcia *et al.*[24] found that 0.2% chlorhexidine added in proportions of 5%, 10%, and 15% to GIC liquid did not significantly affect the compressive strength of GIC.

The decreased compressive strength of antibacterial-modified GIC can be explained in terms of the chemical reactions responsible for the hardening of GIC. During the setting of GIC, calcium ions (Ca^{2+}) and aluminum ions (Al^{3+}) ions released from the glass particles react with the carboxyl groups on the acid polymer and form cross-links. This reaction forms the framework for the hardening of GIC. The presence of antibacterial agents, such as EEP, interferes with the reaction between the glass particles and the acid polymer. Therefore, the number of unreacted particles in the structure increases.[17,25] The decrease in compressive strength is further correlated with ratio changes of the GIC powder and liquid used during mixing, which decreased the concentration of carboxyl groups available for the setting reaction. Experimental cements modified with EEP has compromised ionic interaction between powder and carboxylic group from the liquid. Lower concentrations of carboxyl groups, especially found in the 30% and 35% EEP-modified group, and higher number of unreacted particles adversely affect the cross-links formed in the GIC matrix, resulting in lower compressive strength.[26,27]

In contrast to the results of this study, the addition of certain antibacterial agents has been found to increase the compressive strength of GIC. Wassel *et al.*[28] showed higher compressive strengths with GIC modified with titanium dioxide nanoparticles (TiO_2-NP) and silver nanoparticles (Ag-NP). The increased compressive strength was ascribed to the small nanoparticles occupying the empty spaces between the larger GIC glass particles and acting as additional bonding sites for the polyacrylic polymer, which in turn reinforced the GIC.[28] Singer *et al.*[23] found that adding plant extracts to water in a ratio of 2:1 produced GICs with significantly higher compressive strengths. This is attributed to the presence of silica in the *S. persica* added, which bonds chemically with the matrix and strengthens GIC.

In addition to compromised compressive strength, EEP modification also jeopardizes the color and setting time of GIC. In this study, EEP-modified GIC appeared somewhat yellowish, which can be accredited to the natural yellow-brown color of EEP. When mixed with the light-colored GIC liner, it produced a darker-colored material. Discoloration was an issue encountered in other EEP-modified GIC studies.[8,17] However, discoloration is not an issue when used as a liner because liners are then covered by other restorative materials. Additionally, the setting time of the EEP-modified GIC was slightly prolonged compared to the unmodified GIC. Unmodified GIC and GIC with 25% EEP set in 10 min, whereas GIC with 30% and 35% EEP took 15 and 20 min, respectively, to harden. The longer setting time could be a result of the presence of EEP in the GIC matrix, which interferes with the cement setting reaction, as previously discussed.

The results of the current study suggest that 25% EEP modification did not significantly compromise the compressive strength of GIC. Aside from adequate compressive strength, liners placed in close proximity to the pulp should also provide an adequate seal, minimal leakage, and adequate bond strength to the tooth structure. Thus, further laboratory tests are needed to support the feasibility of using this biomaterial in routine dental practice.

Conclusion

Within the limitations of this study, it can be concluded that the addition of EEP in proportions of 25%, 30%, and 35% decreased the compressive strength of GIC in a proportion-dependent manner. After 24 h, the compressive strength of GIC modified with 25% EEP was not significantly different from GIC alone. Therefore, EEP should be considered for use as a liner material.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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In Vitro Evaluation of the Compressive Strength of Glass Ionomer Cement Modified with Propolis in Different Proportions

by Rosalina Tjandrawinata FKG

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Original Article

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Advita Azalia, Deviyanti Pratiwi, Akhmad Endang Zainal Hasan[1], Rosalina Tjandrawinata, Eddy Eddy

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Keywords: *Compressive strength, ethanolic extracts of propolis, glass ionomer cement, Trigona spp*

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Dental caries remains one of the most common oral diseases worldwide.[1] Currently, minimally invasive dentistry is the approach used in the treatment of deep caries. This treatment involves partial caries removal followed by the application of an adhesive restorative material.[2] Resin-based materials are often used; however, these pose the issue of polymerization shrinkage, which leads to microleakage and postoperative sensitivity.[3,4] Therefore, liners are added to protect dental pulp and to minimize the risks of polymerization shrinkage.[5]

Because of its biocompatibility, adherence to tooth structures, and fluoride release, glass ionomer

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cement (GIC) is among the commonly used dental materials.[6] Its most distinguishing factor is its ability to release fluoride, but its anticariogenic effectivity is still debatable. Several clinical studies have provided inconsistent results regarding the ability of the fluoride released to inhibit the incidence of secondary caries.[7] GIC releases 10ppm of fluoride within the first 48 hours after its application. This level of fluoride release is considered low and less efficacious for providing the desired antibacterial effect.[8]

Liners with effective antibacterial properties are advantageous because they can overcome problems related to persistent cariogenic microorganisms found after partial caries removal. Additional antibacterial properties could help reduce the number of living microorganisms, thereby preventing the development of caries and pulpal infection, which are major causes of patient discomfort.[9,10] Thus, antibacterial additives capable of improving the antibacterial properties of GIC without adversely affecting its mechanical properties are needed.

Propolis is a natural resin material produced by honey bees of the *Trigona* genus, commonly found across the islands of Java, Sumatra, Maluku, and Kalimantan.[11,12] Propolis contains bioactive components with various pharmacological effects, including antibacterial, antifungal, antiviral, antiparasitic, anti-inflammatory, antiproliferative, antioxidant, and anticancer properties. These properties, along with its nontoxic nature and minimal allergic reactions, have made propolis a popular biomaterial in medicine. In dentistry, propolis has been a prominent ingredient in commercial antibacterial toothpaste and mouthwash.[13]

Several studies have concluded that GIC modified with an ethanolic extract of propolis (EEP) has improved antibacterial properties against *Streptococcus mutans* and *Lactobacillus acidophilus*.[14-16] At the same time, it is known that propolis additives may compromise the mechanical properties of GIC.[15,17] Compressive strength is of utmost importance because sufficient strength is needed to withstand the mastication forces within the oral cavity.[18] Ideally, materials used as liners are required to have compressive strengths equal to that of dentin or the permanent restoration placed over it.[19]

It has been proven that GIC with a proportion of 50% EEP can eliminate a number of oral microbiomes, whereas proportions under 25% EEP are less effective. However, greater concentrations of EEP result in GIC with lower compressive strength.[14,15] There are limited studies evaluating the effect of EEP on the compressive strength of GIC, and the effect of EEP from *Trigona* spp. of Garut, Indonesia on GIC has not been evaluated. Taking into account the description above, the current study aimed to evaluate the effect of propolis extracts from Garut, Indonesia in proportions of 25%, 30%, and 35% on the compressive strength of GIC liners.

Materials and Methods

This *in vitro* experiment was conducted from November to December 2022 at the biochemistry laboratory, IPB University, Bogor for extract formulation and the DMTCore Laboratory, Universitas Trisakti, Jakarta for sample testing. Raw propolis collected from species of *Trigona* originating in Garut, Indonesia was cut into small pieces and ground into powder. The propolis powder was then extracted by maceration using 70% ethanol for 48h at 30°C. The extract was filtered using filter paper (No. 41, Whatman, Buckinghamshire, UK), and the solvent was evaporated using a dehumidifier for 24h at 45°C. A total of 0.5g of propolis extract was dissolved in 90% ethanol to a volume of 10mL. Then, 5.5g of maltodextrin (QinHuangDao LiHua Starch Co., Ltd, Hebei, China) was added, and the solution was stirred using ultrasonication for 20min.

GC Gold Label Luting and Lining Cement (GC Corporation, Tokyo, Japan) were used in the current study. Modifications were made by incorporating EEP with GIC liquid at 25% w/w, 30% w/w, and 35% w/w. The number of samples was determined using the Lemeshow formula. A total of 20 samples were made and divided into four groups:

- Group A: GIC (GC Corporation)
- Group B: GIC modified with EEP at 25% w/w
- Group C: GIC modified with EEP at 30% w/w
- Group D: GIC modified with EEP at 35% w/w

The GIC powder, GIC liquid, and EEP paste were measured on an analytical balance (FS-AR210, Fujitsu, Tokyo, Japan) and mixed according to the manufacturer's instructions using a paper pad and plastic spatula. The mixture was placed carefully into cylindrical molds using a plastic filling. The surface was covered with a mylar strip, glass plate, and 2kg weight. After the setting reaction was completed, the sample was removed from the mold. Samples made according to the inclusion criteria with flat, smooth, and unfractured surfaces were stored in a plastic container fully immersed in artificial saliva with a pH of 7 and placed in an incubator (LIB-080M, LabTech, Namyangju, South Korea) at 37°C for 24h.

Samples were prepared using cylindrical molds measuring 6 mm in height and 4 mm in diameter. After 24 h, the samples were dried, and the diameter and height were measured using a digital caliper (Krisbow, Surabaya, Indonesia). The compressive strength was measured using a universal testing machine (AGS-X 5kN, Shimadzu, Tokyo, Japan). The sample was placed in a vertical position, and a force load was applied along the long axis of the sample at a crosshead speed of 1 mm/min.[20]

The compressive strength was computed using the equation:

$$Cs = \frac{4F}{\pi d^2},$$

where *Cs* is the compressive strength (MPa), *F* is the fracture load (N), and *d* is the diameter of the specimen (mm).[21]

Statistical analysis

Statistical tests were performed using statistical package for the social sciences (IBM SPSS Statistics for Macintosh, Version 29.0. Armonk, NY: IBM Corp). Data from the compressive strength test were tested for normality using the Shapiro–Wilk test, and homogeneity was tested using Levene's test. Normally distributed ($P > 0.05$) and homogeneous ($P > 0.05$) data were further analyzed using one-way analysis of variance followed by Tukey's *post hoc* test with a significance level of $P < 0.05$.

Results

Qualitative phytochemical screening was done to detect the presence of secondary metabolites in the propolis extract from *Trigona* spp. of Garut, Indonesia. The results showed that the propolis extract used in the present study acquired five secondary metabolites, namely, terpenoids, flavonoids, alkaloids, steroids, and tannins [Table 1].

The means and standard deviations of the groups' compressive strength are displayed in Figure 1. It can be inferred that the compressive strength of GIC decreased when EEP was added. The data in this study were normally distributed and homogenous. The one-way analysis of variance test obtained a value of $P < 0.001$, which indicated a significant difference between the sample groups tested. Tukey's *post hoc* test revealed a statistically nonsignificant difference between Group B (25% EEP) and Group A (0% EEP, control) $P = 0.385$. In contrast, Group C (30% EEP) and Group D (35% EEP) had significantly lower compressive strengths compared to Group A (unmodified GIC) ($P < 0.05$).

Table 1: Phytochemical test results of EEP from *Trigona* spp

Extract	Phytochemical test	Result	Test Method
Propolis *Trigona* spp.	Terpenoids	+	Qualitative
	Flavonoids	+	
	Alkaloids	+	
	Steroids	+	
	Tannins	+	

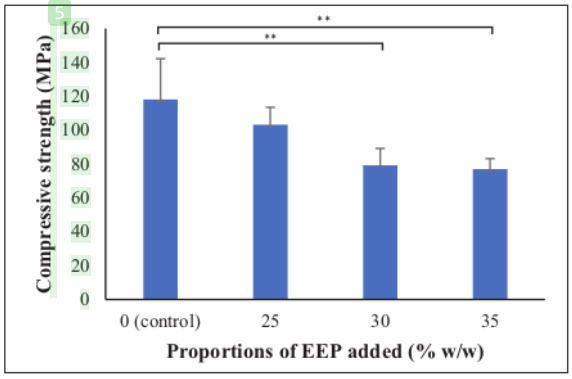

Figure 1: Compressive strength (MPa) results of EEP-modified GIC. $^{**}P < 0.01$

Discussion

EEP is recognized for its antibacterial nature, which is attributed to various natural components, namely phenolic acids, flavonoids, and terpenes.[22] Similar compounds have been found in the EEP from the *Trigona* species of Garut, Indonesia, which was used in this study.

The overall result of this study indicates that EEP-modified GIC has reduced compressive strength compared to unmodified GIC. This result is consistent with the findings of Subramaniam *et al.*,[17] who showed that the addition of 1% w/v propolis significantly reduced the compressive strength of GIC. In addition, this study found that greater proportions of EEP added to GIC resulted in lower compressive strength. The 25% EEP group showed higher compressive strength compared to the 30% and 35% EEP groups. Although GIC modified with 25% EEP is not as effective as GIC with 50% EEP, previous studies have shown that the addition of 25% EEP still has an impact on the antibacterial property of GIC.[14]

Interestingly, the decrease in the compressive strength of GIC with 25% EEP was statistically nonsignificant compared to unmodified GIC. Several studies have concluded that the addition of antimicrobial agents does not significantly affect the compressive strength

of GIC in certain concentrations. Singer *et al.*[23] added a mixture of *Salvadora persica*, *Ficus carcia*, and *Olea europaea* plant extracts to GIC. They concluded that plant extract to water ratios of 1:2 and 1:1 had no significant effects on the compressive strength of GIC.[23] Garcia *et al.*[24] found that 0.2% chlorhexidine added in proportions of 5%, 10%, and 15% to GIC liquid did not significantly affect the compressive strength of GIC.

The decreased compressive strength of antibacterial-modified GIC can be explained in terms of the chemical reactions responsible for the hardening of GIC. During the setting of GIC, calcium ions (Ca^{2+}) and aluminum ions (Al^{3+}) ions released from the glass particles react with the carboxyl groups on the acid polymer and form cross-links. This reaction forms the framework for the hardening of GIC. The presence of antibacterial agents, such as EEP, interferes with the reaction between the glass particles and the acid polymer. Therefore, the number of unreacted particles in the structure increases.[17,25] The decrease in compressive strength is further correlated with ratio changes of the GIC powder and liquid used during mixing, which decreased the concentration of carboxyl groups available for the setting reaction. Experimental cements modified with EEP has compromised ionic interaction between powder and carboxylic group from the liquid. Lower concentrations of carboxyl groups, especially found in the 30% and 35% EEP-modified group, and higher number of unreacted particles adversely affect the cross-links formed in the GIC matrix, resulting in lower compressive strength.[26,27]

In contrast to the results of this study, the addition of certain antibacterial agents has been found to increase the compressive strength of GIC. Wassel *et al.*[28] showed higher compressive strengths with GIC modified with titanium dioxide nanoparticles (TiO_2-NP) and silver nanoparticles (Ag-NP). The increased compressive strength was ascribed to the small nanoparticles occupying the empty spaces between the larger GIC glass particles and acting as additional bonding sites for the polyacrylic polymer, which in turn reinforced the GIC.[28] Singer *et al.*[23] found that adding plant extracts to water in a ratio of 2:1 produced GICs with significantly higher compressive strengths. This is attributed to the presence of silica in the *S. persica* added, which bonds chemically with the matrix and strengthens GIC.

In addition to compromised compressive strength, EEP modification also jeopardizes the color and setting time of GIC. In this study, EEP-modified GIC appeared somewhat yellowish, which can be accredited to the natural yellow-brown color of EEP. When mixed with the light-colored GIC liner, it produced a darker-colored material. Discoloration was an issue encountered in other EEP-modified GIC studies.[8,17] However, discoloration is not an issue when used as a liner because liners are then covered by other restorative materials. Additionally, the setting time of the EEP-modified GIC was slightly prolonged compared to the unmodified GIC. Unmodified GIC and GIC with 25% EEP set in 10 min, whereas GIC with 30% and 35% EEP took 15 and 20 min, respectively, to harden. The longer setting time could be a result of the presence of EEP in the GIC matrix, which interferes with the cement setting reaction, as previously discussed.

The results of the current study suggest that 25% EEP modification did not significantly compromise the compressive strength of GIC. Aside from adequate compressive strength, liners placed in close proximity to the pulp should also provide an adequate seal, minimal leakage, and adequate bond strength to the tooth structure. Thus, further laboratory tests are needed to support the feasibility of using this biomaterial in routine dental practice.

Conclusion

Within the limitations of this study, it can be concluded that the addition of EEP in proportions of 25%, 30%, and 35% decreased the compressive strength of GIC in a proportion-dependent manner. After 24 h, the compressive strength of GIC modified with 25% EEP was not significantly different from GIC alone. Therefore, EEP should be considered for use as a liner material.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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