Majalah Kedokteran Gigi Indonesia
Vol 7 No 2 – August 2021
ISSN 2460-0164 (print), ISSN 2442-2576 (online)
Available online at https://jurnal.ugm.ac.id/mkgi
DOI: http://doi.org/10.22146/majkedgiind.65512

RESEARCH ARTICLE

Effect of Nanofilled Resin-Based Coating on the Compressive Strength of Glass Ionomer Cement – *in vitro*

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ABSTRACT

Glass ionomer cement as one of the restoration materials requires high compressive strength so it can last during functional activity. The latest glass ionomer cement comes with glass hybrid technology and a nanofilled resin-based protective coating which is said to increase the compressive strength of glass ionomer cement. The aim of this study was to analyze the effect of nanofilled resin-based coating and the types of glass ionomer cement materials on their compressive strength. Two types of commercial glass ionomer cement material were used; conventional (Fuji IX GP Extra), and hybrid (EQUIA Forte Fill) glass ionomer cement. Forty cylindrical (4 x 6 mm) samples were prepared in each group. The main group was divided into 4 subgroups (n=10) based on the protective coating used (EQUIA Forte Coat, Varnish, Control, Water + EQUIA Forte Coat). Eight subgroups were immersed in 37 °C distilled water for 7 days, then a compressive strength test was performed using a universal testing machine. The data analysis showed no significant difference in the compressive strength between the two types of glass ionomer cement materials ($p>0.05$). The use of a protective coating was associated with a significant decrease in the compressive strength ($p<0.05$). The use of glass ionomer cement without the application of a protective coating was considered to be quite good because the compressive strength value of the restoration still met the standards of the American Dental Association.

Keywords: compressive strength; glass ionomer cement; nanofilled resin-based coating

INTRODUCTION

Dental caries is a process that involves microorganisms, which are present in dental plaque, causing a disturbance in the mineral balance of the teeth due to the production of microbiota acid resulting in demineralization.[1] According to Indonesia Basic Health Research 2013, the proportion of dental and oral problems was 25.9% which increased to 57.6% in Indonesia Basic Health Research 2018.[2,3] It can be said that caries is one of the problems that needs serious attention. A tooth that has suffered from caries should be immediately restored. The concept of minimally invasive dentistry emphasizes that teeth which require restoration need a cavity preparation as minimally as possible.[4,5] Minimal preparation will conserve more tooth structure that can repair themselves with a remineralization approach. Glass ionomer cement is one of the materials that can be used for this concept.[6,7]

Many studies have reported that the compressive strength of conventional glass ionomer cements in posterior tooth is significantly lower than those of other restorative materials such as compomer or composite resin.[8] Providing a protective coating is said to protect glass ionomer cement from environmental exposure during the maturation process to obtain maximum strength from the restorative material.[9,10] In 2015, a new type of glass ionomer cement with glass hybrid technology was developed. One of its trademarks is EQUIA Forte Fil which is produced by GC Corporation, through the introduction of ultrafine, highly reactive glass particles, dispersed within the conventional glass ionomer structure. With the addition of a higher molecular weight of polyacrylic acid, the new glass hybrid formulation builds a high restorative strength. This restoration material is also accompanied by a nanofilled resin-based protective coating that produces a tougher resin matrix which is named EQUIA Forte Coat.[11]

Compressive strength is considered an important indicator of a restoration because high compressive strength is required to withstand masticatory forces.[12] A compressive strength test is the only indicator that can identify the true strength of a restoration because it has a similar pattern to the functional activity during mastication.[13,14] To date, several studies have compared this glass hybrid GIC with several other dental restorative materials. However, there is inadequate research on the compressive strength of glass hybrid GIC compared to conventional GIC. In addition, there are only a few studies that compare the effect of nanofilled resin-based coating with varnish on the compressive strength of GIC restorations. Therefore, it is necessary to conduct research to determine the effect of nanofilled resin-based coating on the compressive strength of conventional and glass hybrid GIC.

MATERIALS AND METHODS

This was laboratory experimental research. The research was conducted at DMT Core (Dental Materials and Testing Center of Research), Faculty of Dentistry, Trisakti University.

A stainless-steel mold with two cylindrical holes measuring 4 mm in diameter and 6 mm in height was used to make the sample. The sample used a glass ionomer cement capsule. The inclusion criteria for the research sample were GIC cylinders with a flat surface, and free from contamination of other materials. The exclusion criteria were GIC cylinders with an imperfect shape.

The stainless-steel mold was given a thin layer of vaseline. The glass ionomer cement capsule was mixed on the HSM3 High Speed Mixer for 10 seconds, and placed into the mold until it was full. A polyester strip and a glass plate were placed on top of the mold for 60 seconds. The samples were removed, and those with an imperfect shape were discarded (Figure 1). There were 2 main groups, namely EQUIA Forte Fil and Fuji IX GP Extra, with 4 subgroups in each group. Subgroup A consisted of the samples treated with EQUIA Forte Coat. Subgroup B consisted of the samples treated with GC Fuji Varnish. Subgroup C was the control group with untreated samples. Subgroup D consisted of the samples with water immersion treatment for 5 minutes, then treated with EQUIA Forte Coa=hv:dt. The protective coating covered the entire surface of the sample. There were 10 samples for each subgroup, and there were a total of 80 samples.

After treated, all the samples were immersed in distilled water in an incubator at 37 ℃ for 7 days (Figure 2). The samples were then tested on a Universal Testing Machine by applying compression pressure at a speed of 1.0 mm/minute until cracks were seen (Figure 3). The compressive strength test was carried out by the Saphiro-Wilk normality test, followed by an analysis using two-way ANOVA and Tukey's HSD Post Hoc comparison test to compare between the groups, with a significance level of $p<0.05$.

RESULTS

The mean compressive strength of the glass ionomer cement based on the types of the material

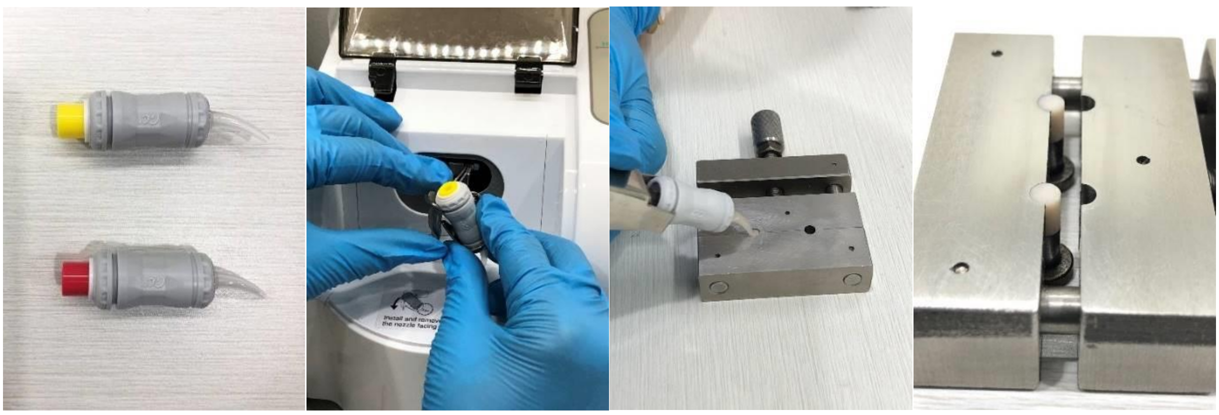

Figure 1. Preparation stages of glass ionomer cement samples

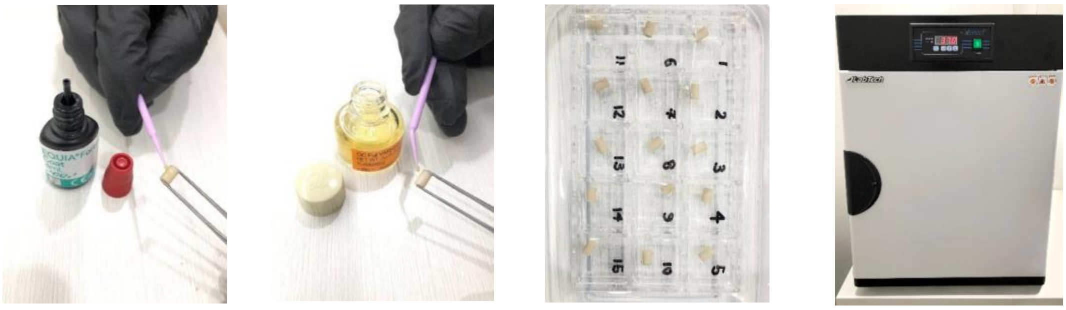

Figure 2. Treatment of glass ionomer cement samples

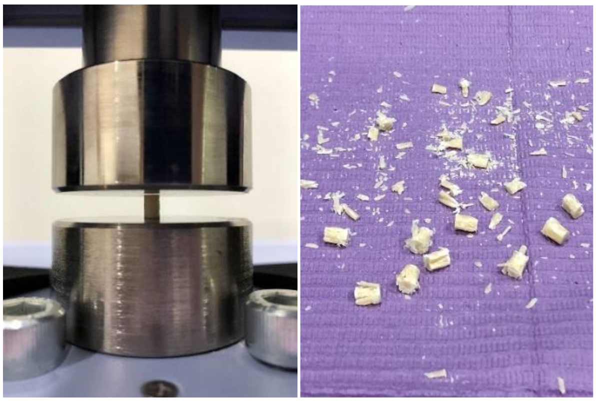

Figure 3. Testing stages of glass ionomer cement samples

and treatment can be seen in Table 1. There was a significant difference in the compressive strength of the protective coating in the two types of glass ionomer cement tested.

The Saphiro-Wilk normality test was done to determine the data distribution. The results showed that the data were normally distributed ($p>0.05$). Based on the results of the normality test, the statistical test was carried out using the two-way ANOVA test and the data are presented in Table 2. The results of the two-way ANOVA test showed no significant difference in the compressive strength between the two types of glass ionomer cement ($p>0.05$), but the protective coating treatment had a significant difference ($p=0.000$). When combined between the types of glass ionomer cement and protective coating treatment, there was a significant difference in the compressive strength ($p= 0.000$).

Based on the multiple comparison tests using the Tukey's HSD Post Hoc test shown in Table 3, it was proven that EF had significantly higher compressive strength than all the subgroups, except GE ($p= 0.418$). EF (EQUIA Forte Fil control group) value was higher than GE (Fuji IX GP Extra control group), but not significantly different. Meanwhile, GEF was shown to have significantly lower compressive strength compared to all the sub-groups. Sequentially, the 3 subgroups with the highest compressive strength values are EF, GE, and GEV.

Table 1. Data of mean and standard deviations of the compressive strength (MPa) of glass ionomer cement by type of material and treatment

Type of material	Treatment	Code	$\bar{x}$ ± SD
Glass hybrid ionomer cement (EQUIA Forte Fil)	EQUIA Forte Coat	EFF	93.38 ± 12.03
	Varnish	EFV	113.62 ± 28.67
	Control	EF	161.10 ± 25.96
	Water + EQUIA Forte Coat	EFAF	94.36 ± 15.80
Conventional glass ionomer cement (Fuji IX GP Extra)	EQUIA Forte Coat	GEF	59.54 ± 9.78
	Varnish	GEV	133.18 ± 11.50
	Control	GE	143.08 ± 27.10
	Water + EQUIA Forte Coat	GEAE	95.32 ± 7.84

Table 2. The results of statistical tests using two-way ANOVA

Source	Type III Sum of Squares	df	Mean Square	F	p
Corrected Model	75164.554[a]	7	10737.79	29.465	0.000*
Type of GIC material	1228.62	1	1228.62	3.371	0.070
Protective coating	65896.09	3	21965.36	60.274	0.000*
Type of GIC material and protective coating	8039.84	3	2679.95	7.354	0.000*

* significant at p< 0.05

Table 3. The results of multiple comparisons using Tukey's HSD Post Hoc

Group (I)	Group (J)	Mean Difference (I-J)	P	Differences
EFF	EFV	-20.24315	0.271	Not significant (-)
	EF	-67.72357*	0.000	Significant (-)
	EFAF	-0.97639	1.000	Not significant (-)
	GEF	33.84392*	0.004	Significant (+)
	GEV	-39.80067*	0.000	Significant (-)
	GE	-49.69957*	0.000	Significant (-)
	GEAE	-1.93556	1.000	Not significant (-)
EFV	EF	-47.48042*	0.000	Significant (-)
	EFAF	19.26676	0.332	Not significant (+)
	GEF	54.08707*	0.000	Significant (+)
	GEV	-19.55752	0.313	Not significant (-)
	GE	-29.45642*	0.020	Significant (-)
	GEAE	18.30759	0.397	Not significant (+)
EF	EFAF	66.74718*	0.000	Significant (+)
	GEF	101.56749*	0.000	Significant (+)
	GEV	27.92290*	0.033	Significant (+)
	GE	18.02400	0.418	Not significant (+)
	GEAE	65.78801*	0.000	Significant (+)
EFAF	GEF	34.82031*	0.003	Significant (+)
	GEV	-38.82428*	0.001	Significant (-)
	GE	-48.72318*	0.000	Significant (-)
	GEAE	-0.95917	1.000	Not significant (-)
GEF	GEV	-73.64459*	0.000	Significant (-)
	GE	-83.54349*	0.000	Significant (-)
	GEAE	-35.77948*	0.002	Significant (-)
GEV	GE	-9.89890	0.941	Not significant (-)
	GEAE	37.86511*	0.001	Significant (+)
GE	GEAE	47.76401*	0.000	Significant (+)

* significant at p< 0.05

Description:

Not significant (+) : Not significant, the value of group (I) > group (J).
Not significant (-) : Not significant, the value of group (I) < group (J).
Significant (+) : Significant, the value of group (I) > group (J).
Significant (+) : Significant, the value of group (I) < group (J).

DISCUSSION

Glass Ionomer Cement (GIC) is a combination of polyalkenoic acid as a liquid and calcium or strontium fluoroaluminosilicate glass as a powder.[15-17] The glass composition of each GIC is different, but it is always made from silica, calcium, alumina, and fluorine with a particle size of 4-50 μm.[18]

The GIC sensitivity to powder-to-liquid ratio, mixing process, and long setting time can cause GIC restorations to have low compressive strength, and lower ability to be placed in areas with high stress. Contamination in the early stages of hardening can reduce mechanical strength and make GIC restorations susceptible to erosion and abrasion.[9,19]

The compressive strength of a restoration material is an important indicator of a restoration because high compressive strength is required to withstand forces arising from functional activity and chewing in the mouth.[20,21] Increased compressive strength will increase GIC resistance in the long run, making it a good restorative material.[19]

The strength of the GIC material is influenced by several factors, including the composition of the material, the powder to liquid ratio, and the material manipulation method.[22] The application of a protective coating after restoration is said to increase the compressive strength of GIC.[8] The first polymerization-based protective coating, namely G-coat, produces a uniform micro-lamination on the surface of the restoration, filling in any gaps and creating a protective coating 35-40 μm in thickness. This coating produces a smooth and shiny surface, strengthens, protects, and increases the hardness of all GIC materials.[19]

Previous research revealed that the compressive strength of GIC which was given a protective coating was higher.[19,23] However, contradictory results were obtained after conducting this research, i.e., the application of EQUIA Forte Coat produced a much lower compressive strength compared to the control group in both types of GIC materials. Similar research results were disclosed by Bohner and Prates, that the protective coating of varnish reduced the compressive strength of GIC restorations.[21]

The protective coating applied in this research covered the entire surface of the GIC sample to provide full isolation during the maturation process. This was done on the premise that the real function of the protective coating is to prevent the maturation process from being disturbed by rehydration or excess dehydration because it can interfere with the maturation process.

The sub-group treated with the varnish application on both types of glass ionomer cement materials found that the mean compressive strength was higher than the sub-group treated with the EQUIA Forte Coat application. When testing the sample, it was found that some of the varnish layer was lost. The same thing was found in the study by Gorseta et al.[23] The lost part of the varnish layer is thought to be due to the main composition of the varnish, namely 60-70% isopropyl acetate, which is quite soluble in water.

Other researchers, namely Pilo et al, stated that GIC which was given a protective coating produced a lower shear strength compared to unprotected GIC. They said that applying a protective coating to the surface of the restoration makes it difficult for GIC to absorb water during the gelation stage, thereby preventing the attainment of the maximum mechanical properties of GIC.[24] Hankins et al., stated that the concept of applying a protective coating provides a protective effect against water absorption, whereas rehydration actually has a beneficial effect after passed the initial phase of GIC hardening.[25] This is similar to what the EQUIA Forte Coat application subgroup showed in this study. Ilie revealed that the improvement in the mechanical properties of GIC that manufacturers have done today eliminates the need for protective applications such as varnish.[20]

The GIC samples in this study were stored in distilled water and the conditions in the oral cavity were not considered. GIC character is said to change based on the osmolarity of the storage medium, so this may give different results.[26] However, McKenzie et al, revealed that there was no significant increase in the mechanical properties of GIC soaked in saliva.[27] Other researchers have strengthened the previous statement, that soaking in artificial saliva did not have a significant difference with soaking in distilled water, but the length of immersion time had an effect on increasing the mechanical properties of GIC.[9,10]

The same thing was stated by Shintome et al, that the length of immersion in distilled water increased the value of GIC strength.[28] This strengthens the opinion that the compressive strength of GIC is regulated by the balance of water absorption from the beginning to the end of the gelation stage.[9,28] This explains the control subgroup which had higher compressive strength than the treatment sub-groups.

In addition, the mean compressive strength of all the treatment subgroups did not meet the minimum standards set by the American Dental Association specification number 96 regarding ionomer restorations. The minimum compressive strength value is 130 MPa. However, it is possible that the involvement of voids that occur during the mixing process which cannot be detected with the naked eye can contribute to the difference in GIC compressive strength. Voids are defined as trapped air that creates empty space.[29] In contrast to the other subgroups, the two types of GIC materials in the control group met the ADA standard with a mean value of 143.08 MPa for conventional GIC and 161.10 MPa for glass hybrid GIC.[30]

The mean compressive strength of EQUIA Forte Fil without a protective coating was found to be the highest among the entire sample groups, while Fuji IX GP Extra without a protective coating ranked the second. However, the values of the two were not significantly different. The effect of the protective coating in this study resulted in a decrease in the compressive strength of all the treatment groups compared to the control group. The decrease in the compressive strength varied between 7-30% in the varnish group, and a decrease of 42-58% in the EQUIA Forte Coat group. These results suggested that the use of a protective coating did not provide good results in GIC restorations.

In GIC restoration, it is possible that on clinical application there will be a compensation. GIC restoration in vital teeth is said to occur in the process of absorption of fluids originating from the dentinal fluid and the pulp chamber, allowing the fluid to diffuse until it reaches between the teeth and the restorative material. In addition, previous studies have revealed that the use of a protective coating can reduce the surface roughness of the restoration, thereby minimizing plaque adhesion and improving the aesthetics of the restoration.[31] Likewise, the flexural strength is said to increase significantly after the application of protective coating.[8,10] This research can be developed by considering the modification of the protective coating application method to the sample. Involving more samples will increase the data accuracy.

CONCLUSION

The application of nanofilled resin-based coating on GIC has the effect of decreasing the compressive strength value significantly. Based on the type of GIC material used, there is no significant difference between glass hybrid GIC and conventional GIC. The use of GIC without the application of a protective coating is considered to be quite good because the compressive strength value of the restoration meets the standards of the American Dental Association.

Conflict of interests

The authors have no conflict of interests.

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