Journal of Dentistry Indonesia

Volume 26
Number 1 *April*

Article 3

4-30-2019

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Recommended Citation
Bekmezoğlu, Z. E., Güngör, Ö. E., & Karayilmaz, H. Comparison of Glass Carbomer, Giomer, Glass Ionomer and Resin Fissure Sealants on Permanent Molar Teeth. J Dent Indones. 2019;26(1): 10-18

Journal of Dentistry Indonesia 2019, Vol. 26, No. 1, 10-18
doi: 10.14693/jdi.v26i1.1293

ORIGINAL ARTICLE

Comparison of Glass Carbomer, Giomer, Glass Ionomer and Resin Fissure Sealants on Permanent Molar Teeth

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ABSTRACT

Objectives: To compare the success of the newly developed glass carbomer-based fissure sealant to resin, glass ionomer, and giomer-based fissure sealants in permanent molar teeth according to the modified United States Public Health Service criteria. **Methods:** Glass carbomer-based fissure sealant GCP Glass Carbomer, glass ionomer-based fissure sealant Fuji Triage, giomer-based fissure sealant Beauti Sealant, and resin-based fissure sealant prevent seal were applied using invasive/non-invasive methods to extracted human molars. Specimens were randomly assigned into three groups based on the simulated aging procedure time. **Results:** According to the retention score results of Group 1, the invasive giomer material yielded the highest score in the Group. The retention score results of Group 2 showed that the invasive resin subgroup had the highest alpha-score. Furthermore, we found that the invasive GIS, non-invasive giomer, and invasive giomer subgroups had similar alpha-scores within Group 2. The glass carbomer and glass ionomer cement subgroups were unsuccessful in maintaining their edge integrity, edge coloring, surface roughness, and surface coloring. **Conclusion:** Thus, glass ionomer cements (GIC) and glass carbomer-based materials can be useful alternatives to residual monomers contained in resin-based fissure sealants. For patients who can be controlled regularly, glass carbomer fissure sealant can be applied using invasive methods.

Key words: Fissure sealant, glass carbomer, glass ionomer, giomer, resin

How to cite this article: Zeliha E. Bekmezoğlu, Özge E. Güngör, Hüseyin Karayilmaz. Comparison of glass carbomer, giomer, glass ionomer and resin fissure sealants on permanent molar teeth. J Dent Indones. 2019;26(1):10-8

INTRODUCTION

Fissure sealant applications have been one of the most effective methods used since the 1960s to prevent caries formation in pits and fissures, which are areas of concern regarding the potential formation of caries in preventive dentistry.[1,2] Many materials have been used previously as fissure sealants. These include cyanoacrylates, polyurethanes, polycarboxylate cements, bisphenol glycidyl methacrylate (Bis-GMA) resins, glass ionomer cements (GIC), resin-modified glass ionomer cements (RMGIC), polyacid-modified composite resins (PMKR), ormocers (organically modified ceramics) and giomers.[1,3] Today, the most commonly used fissure sealant materials are comprised of resin and GIC-based formulas.[2]

The advantages of GIC-based fissure sealants are their anti-caries effects due to fluoride release, biocompatibility, ability to chemically bond to tooth tissue, resistance to acid erosion, and having comparable thermal expansion coefficients to hard dental tissues.[4-7] The use of GIC-based fissure sealant provides great convenience especially for controlling moisture in erupting permanent first molar teeth in children.[8] However, disadvantages of GIC-based fissure sealants include low resistance to fracture, short working time, long setting time, the development of structures that are susceptible to moisture contamination during the setting process, high level of microleakage, and sub-optimal color matching compared to composite resins.[4,5] Giomer and glass carbomer-based fissure sealants have been developed in recent years to provide solutions to the disadvantages associated with these two materials. Giomer is a new hybrid material containing the fluoride release and recharge properties of GIC with the aesthetic, polishable, and biocompatible properties of the composite resins.[9] A resin matrix is formed containing pre-reacted glass ionomer fillers (PRG).[10-12] Giomers comprise of the following: Bis-GMA, Triethylene glycol dimethacrylate (TEGDMA),

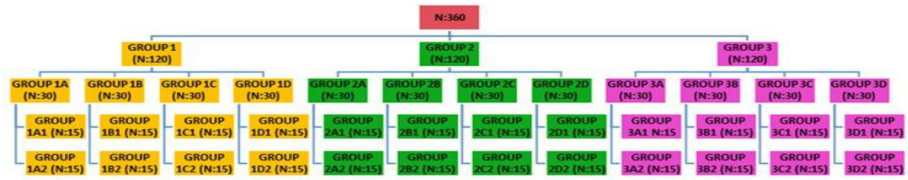

Figure 1. The diagram of main groups and subgroups

Group 1A1, 2A1, 3A1: Non-invasive technique of glass carbomer fissure sealant application
Group 1A2, 2A2, 3A2: Invasive technique of glass carbomer fissure sealant application,
Group 1B1, 2B1, 3B1: Non-invasive technique of glass ionomer fissure sealant application,
Group 1B2, 2B2, 3B2: Invasive technique of glass ionomer fissure sealant application,
Group 1C1, 2C1, 3C1: Non-invasive technique of giomer fissure sealant application,
Group 1C2, 2C2, 3C2: Invasive technique of giomer fissure sealant application,
Group 1D1, 2D1, 3D1: Non-invasive technique of resin fissure sealant application,
Group 1D2, 2D2, 3D2: Invasive technique of resin fissure sealant application

inorganic glass filler, aluminum oxide, silica, PRG filler and DL-camphorquinone.[13] In addition to releasing various ions such as fluoride, silicon, and strontium, S-PRG fillers also release metal ions to prevent bacterial growth.[14]

The glass carbomers were developed by reducing the powder particles to nano-size, adding carbon chains to the powder, and adding glass-containing fluorapatite as the second filler.[15] One of the biggest advantages of using glass carbomer cements in pediatric dentistry is its tolerance to moisture. It is particularly useful for children who are struggling to maintain saliva isolation. It is also a biocompatible material since it does not contain fillers like Bis-GMA.[15,16]

Although published studies had revealed the disadvantages of giomer (water sorption and discoloration[11]), glass carbomer (microleakage[17] and low retention ratio[18]) and resin-based (technique sensitivity[19]) fissure sealants, there few studies in the literature focusing on the success of glass carbomer and giomer-based fissure sealants. The purpose of our study is to assess the success of this newly developed glass carbomer-based fissure sealant using the modified United States Public Health Service (USPHS) criteria, and compare its success with resin, glass ionomer and giomer-based fissure sealants in permanent molar teeth.

METHODS

This study protocol was approved by University Faculty of Medicine Clinical Research Ethics Committee with Reference No. 425 (20.07.2016). A total of 360 permanent molar teeth, which were extracted for orthodontic, prosthetic, or periodontal reasons in the Oral and Maxillofacial Surgery Clinic of University Faculty of Dentistry, were used in this laboratory study. Inclusion criteria were as follows: teeth must not contain caries, restoration and/or hypomineralization, and had an indication for fissure sealant. Plaque and soft tissue remnants on the teeth were removed via thorough cleaning under running water. The teeth were stored in distilled water until the time of the experiment. The teeth were embedded in plastic blocks using acrylic (Dentarum Orthoacryl, Deutschland) prepared in sizes that were compatible with the chewing simulator. The following sealant materials were used: glass carbomer-based fissure sealant GCP Glass Carbomer (GCP Dental, The Netherlands), GCP Gloss Seal (GCP Dental, The Netherlands), glass ionomer-based fissure sealant Fuji Triage (GC Fuji Triage White, GC US), giomer-based fissure sealant Beauti Sealant (BS; Shofu Inc., Kyoto, Japan), Beauti Sealant Primer (BS; Shofu Inc., Kyoto, Japan) and resin-based fissure sealant Prevent Seal (ITENA, France). The fissure sealant used in our study did not require the application of acid for etching the enamel surface before applying the fissure sealant.

The teeth were divided randomly into three main groups containing 120 teeth per Group **(Groups 1, 2, and 3).** Each Group was randomly divided into four subgroups (**A**: Glass carbomer based fissure sealant, **B**: Glass ionomer-based fissure sealant, **C**: Giomer-based fissure sealant, **D**: Resin-based fissure sealant; N = 30). These four subgroups were divided into two smaller subgroups for fissure sealant application with a non-invasive and invasive technique. (N =15 per Group). All main groups and subgroups are shown in Figure 1.

After fissure sealants were applied, teeth in Group 1 were subjected to 60,000 cycles of a chewing simulator. This simulator was equipped with a thermal cycling feature (Mod Dental, 2015, Turkey) which exposed the teeth to temperatures of 5 degrees for 1 minute and 55 degrees for a total of 2 minutes. This treatment was equivalent to the effects of 3 months of aging.

Table 1. In vitro evaluation criteria (Modified USPHS criteria)

Criteria	Feature	Method (Eye/Sond)
Retention		
Alpha 1	Fissure sealant in the mouth	E
Bravo 2	Partial loss in sealant	E
Charlie 3	Complete loss of fissure sealant	E
Edge Integrity		
Alpha 1	No restraint margins on examination with sond	E/S
Bravo 2	There is not much more than 1/3 of the margins, but there is a slight stab	E/S
Charlie 3	More than 1/3 of the margins of the restorations have penetration and / or stabbing	E/S
Edge Coloring		
Alpha 1	No visible coloration	E
Bravo 2	There is slight coloration in one or several areas	E
Charlie 3	There is violent coloration in one or several areas	E
Surface Roughness		
Alpha 1	Smooth surface available	E/S
Bravo 2	Light roughness available	E/S
Charlie 3	The surface is completely rough	E/S
Surface Coloration		
Alpha 1	No coloring	E
Bravo 2	Light coloring available	E
Charlie 3	Severely colored	E

Group 2 was subjected to 120,000 cycles of a chewing simulator with the following temperature exposures: 1 minute at 5 degrees and 1 minute at 55 degrees for a total of 2 minutes. This treatment was equivalent to the effects of 6 months of aging. Group 3 was subjected to 250,000 cycles with a chewing simulator and exposed to the following temperatures: 1 minute at 5 degrees and 1 minute at 55 degrees for a total of 2 minutes. This treatment was equivalent to the effects of 12 months of aging). The chewing simulations were applied with a maximum force of 250 N, two axes, at 90 mm/s maximum axis speed, and at 3.0 Hz maximum axis frequency. After the completion of the laboratory procedures, all the samples (360 pieces) were assessed with sound and eyes by the same physician to evaluate retention, edge integrity, edge coloring, surface roughness and surface coloration according to the modified United States Public Health Service (USPHS) criteria (Table 1).

In addition, a total of 24 samples in Group 2 and 3 were evaluated with AFM device (Park system, XE7, Korea) for investigating the roughness of the tooth surface. Imaging was done in the air environment and a half-way mode, with silicone tip. During the examination, sample imaging was performed by taking an area image of 45 × 45 μm^2 at a resolution of 256 × 256 pixels.

Descriptive statistics (minimum, maximum, mean, and standard deviation), reliability analysis, and comparison tests were performed by entering obtained data into the SPSS package program (SPSS 18.00 for Windows, Chicago, IL, USA).

Qualitative data obtained during the study as well as comparisons between groups were analyzed using the Kruskal-Wallis, Mann-Whitney U, Wilcoxon, and Chi-square tests. Interactions between two groups were evaluated using the Pearson correlation test. Survival time was analyzed using the Kaplan-Meier method. The results were evaluated at 95% confidence interval with a $p < 0.05$ significance level.

RESULTS

Statistically significant differences were found between the materials in all parameters examined as part of groups 1, 2, 3 ($p < 0,05$). The p values obtained from the statistical analysis of the Groups 1, 2, and 3 material results are shown in Table 2.

Assessment of the teeth in Group 1 according to modified USPHS criteria

Among the teeth in Group 1 that were examined, those within the invasive giomer material subgroup had the

Table 2. The ‘p values’ obtained from the statistical analysis of the results of the materials in all parameters in groups 1, 2, 3.

			Retention	Edge Integrity	Edge Coloring	Surface Roughness	Surface Coloration
	N:120	Group 1	.000	.000	.001	.000	.000
P Values	N:120	Group 2	.000	.019	.029	.009	.036
	N:120	Group 3	.000	.034	.017	.001	.003

(*p <0.05* significant difference)

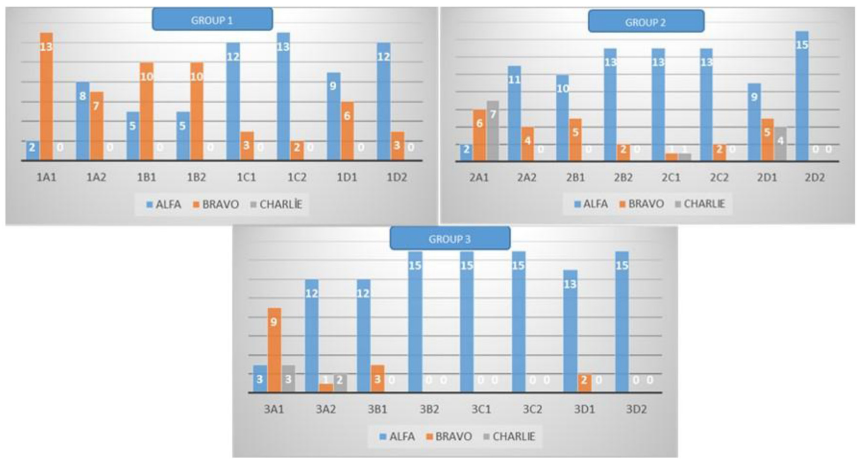

Figure 2. Retention scores for Group 1, 2, and 3

highest alpha-score (86.2%). However, similar scores were obtained in the non-invasive giomer, non-invasive resin, and invasive resin subgroups. There was no statistically significant difference between these four subgroups ($p > 0.05$). The non-invasive glass carbomer subgroup was more unsuccessful than the invasive glass carbomer, non-invasive, and invasive giomer, non-invasive resin, and invasive resin subgroups. No significant difference was observed between the glass carbomer groups and glass ionomer cement subgroups (Figure 2). The invasive resin, non-invasive giomer, and invasive giomer subgroups were the most successful in terms of maintaining edge integrity (66.6%, 53.3%, and 53.3%). The invasive giomer Group had the highest success rates in terms of maintaining edge coloring (60%), preventing surface roughness (66.6%) and maintaining surface coloration. On the other hand, the least successful Group in terms of maintaining surface coloration was the non-invasive glass ionomer Group.

Assessment of the teeth in Group 2 according to modified USPHS criteria

Among the subgroups within Group 2 were examined, invasive resin subgroup had the highest alpha-score (100%), while the invasive GIS, non-invasive giomer, and invasive giomer subgroups all had similar alpha-scores. There was no statistically significant difference between these four subgroups ($p > 0.05$). The non-invasive glass carbomer was the most unsuccessful subgroup in terms of alpha-score (Figure 2).

The glass carbomer and glass ionomer cement subgroups were found to be unsuccessful in regard to maintaining edge integrity; the rate of failure for the non-invasive glass carbomer subgroup was 50% and the rate of failure for the non-invasive glass ionomer subgroup was 60%). These two groups were also unsuccessful at maintaining edge coloring; the rate of failure for the non-invasive glass carbomer was 50% and 60% for the non-invasive glass ionomer. The rate of failure to prevent surface roughness was 73.3% among the invasive glass carbomer subgroup was 73.3% and 66.6% for the invasive glass ionomer subgroup. Finally, the failure to maintain and surface coloring was 60% for the invasive glass carbomer was 60% and 66.6% for the invasive glass ionomer.

Assessment of the teeth in Group 3 according to modified USPHS criteria

The invasive GIC, non-invasive giomer, invasive giomer, and invasive resin groups were the most successful subgroups overall in terms of alpha-scores (100%). No statistically significant difference was observed among the invasive glass carbomer, non-invasive GIC, and non-invasive resin subgroups, but the non-invasive glass carbomer was the most unsuccessful Group overall (Figure 2).

In regard to maintaining edge coloring, the most successful groups was the non-invasive GIC subgroup (86%), while the least successful were the non-invasive (41.6%) and invasive glass carbomer (61.5%) subgroups.

Table 3 Mean Ra values of the groups

		Glass carbomer- based fissure sealant	GIC-based fissure sealant	Giomer- based fissure sealant	Resin-based fissure sealant
Mean Ra values (μm)	Group 2	1.19	1.49	1.06	0.6
	Group 3	1.06	2.13	1.10	1.06

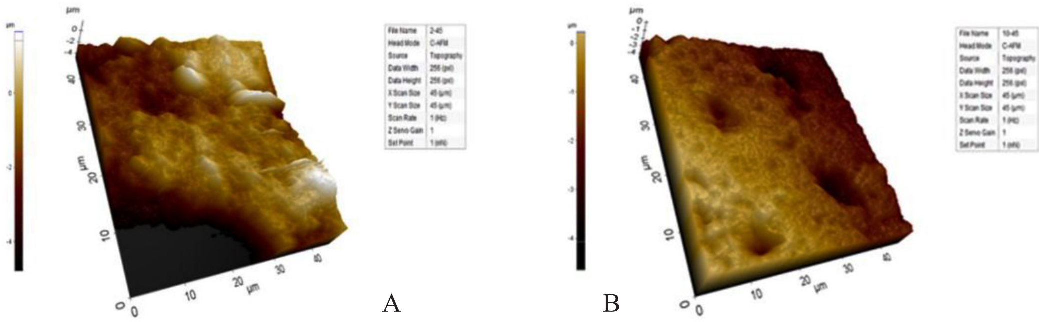

Figure 3. AFM images of glass carbomer-based fissure sealant of (A) Group 2 and (B) Group 3

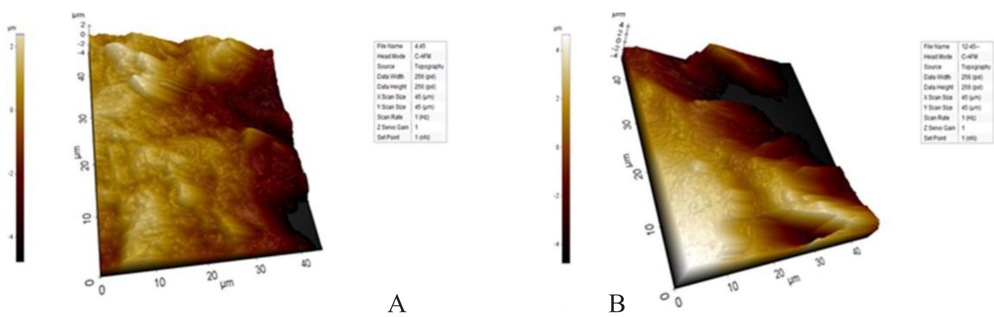

Figure 4. AFM images of glass ionomer-based fissure sealant from (A) Group 2 and (B) Group 3

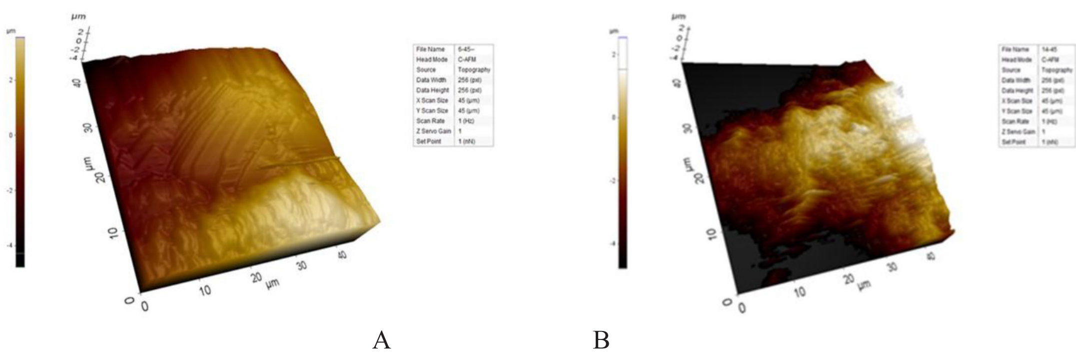

Figure 5. AFM images of giomer-based fissure sealant from (A) Group 2 and (B) Group 3

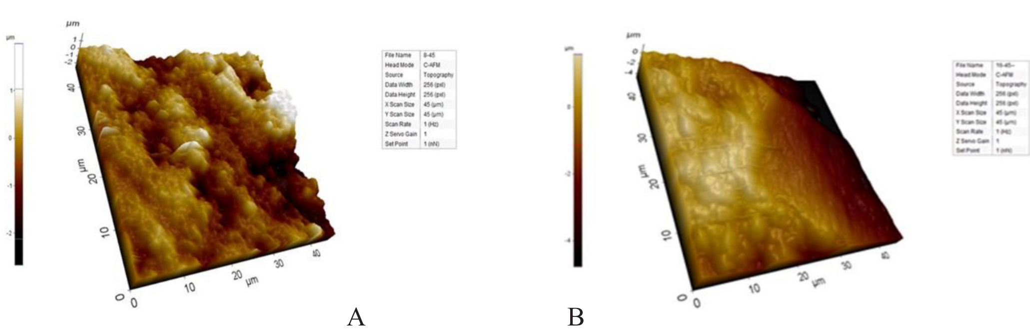

Figure 6. AFM images of resin-based fissure sealant from (A) Group 2 and (B) Group 3

Atomic Force Microscopy Findings

While reviewing the success of the restorative materials, properties such as retention, edge integrity, secondary caries formation, and fluoride release were taken into account. Surface roughness is one of the factors affecting the clinical success of restorative materials, since an ideal restorative material should be able to maintain smoothness for a long time in the oral environment.[20] An increase in surface roughness it affects the coloring of the material and makes it more susceptible to plaque accumulation. The consequences of these factors include gingival irritation, recurrent decay, acceleration of wear, and tactile perception.[21]

Ra, the mean roughness value, refers to the arithmetic average of absolute sums of all surface irregularities (height and depth) at a given measurement distance.[22] A 0.3 μm increase in surface roughness can be detected with the tongue edge. This rough feeling leads to reduced comfort for the patient. The critical value for average surface roughness is 0.2 μm, meaning that a value greater than 0.2 μm poses a risk for plaque formation and bacterial adhesion.[23] SEM and AFM are preferred techniques for measuring surface roughness.[24]

Three samples each were taken from the Groups 2 and 3, a total of 24 samples were applied by invasive technique, were used surface roughness measured by the AFM device. The Ra (mean roughness value) values for each example are calculated using the AFM software program (XEI, Park system, Korea). The averages for the Ra values in each Group were calculated. Ra values of the groups are shown in Table 3.

In Group 2, the most successful subgroup, as defined by the lowest mean Ra value, was the resin-based fissure sealant (mean Ra value: 0.6 μm) while the most unsuccessful subgroup was the GIC-based fissure sealant (mean Ra value: 1.49 μm). In Group 3, the most successful subgroups were the giomer-based fissure sealant and glass carbomer-based fissure sealant (mean Ra values: 1.06 μm). Within Group 3 the most unsuccessful subgroup was the GIC-based fissure sealant (mean Ra value: 2.18 μm). The images captured by the AFM device for Groups 2 and 3 are shown in Figures 3–6.

DISCUSSION

The application of preventive dentistry techniques is becoming more important within the field of pediatric dentistry as new applications and materials are introduced to the field. Fissure sealant applications are still the preferred treatments for preventing caries and tooth decay.[25,26] Nowadays, the most preferred fissure sealant materials are GIC-based and resin-based [16]. Studies have concluded that the most successful material in preventing occlusal surface caries is a resin-based fissure sealant.[26,27] However, the release of residual monomers from resin-based fissure sealant is a significant disadvantage to this material.[28] For this reason, studies were performed using a variety of alternative materials. Researchers have reported that one of the most important criteria for determining the success of the fissure sealant is the level of retention of the material in many studies, glass ionomer-based fissure sealants has shown low retention in response to stress.[27,29]

In our study, as in other studies, the GIC-based fissure sealant had lower retention compared to the resin and giomer sealants (evident in Group 1). In our study, there was no significant difference between success of the glass carbomer fissure sealant with invasive method and other subgroups. If an invasive technique is required, the glass carbomer fissure sealant may be considered as an alternative to resin-based fissure sealants.

A study conducted by Gorseta et al. studied the retention of the glass carbomer fissure sealant for 12 months in comparison to the retention of the resin-based fissure sealant.[30] It showed findings similar to those from our study, where both materials exhibited similar retention rates.

In our study, when non-invasive techniques were used in fissure sealant applications, the giomer-based fissure sealant was found to be the most successful. We think that this fissure sealant may have improved the adhesion by providing better penetration into the depths of the pits and fissures. In our study, the success of the BS may be attributed its inclusion of dual adhesive monomers, which increase the primer penetration capability. There are studies showing that micromechanical properties of giomers are better than resin-based materials.[19] Shimazu et al. evaluated the shear bond strengths of two different resin-based fissure sealants and giomer-based fissure sealant.[31] The results of the study indicated that there is no statistically significant difference between the shear bond strengths of these materials. As a result of this study, the author recommended fluoride-releasing giomer as a fissure sealant material.

In Group 2 and Group 3, the glass carbomer applied with the non-invasive technique had the lowest retention rate and the success of the glass carbomer fissure sealant decreased over time. Chen et al. used micro-CT to evaluate the microleakage of the glass carbomer and GIC-based fissure sealant, and they found that the glass carbomer fissure sealant had numerous cracks (broken lines).[32] In our study, the gradual reduction of the retention rate of the glass carbomer fissure sealant may be due to cracks that may have formed within the material.

The ability to successfully cover pits and fissures and ideal marginal adaptation requires a fissure sealant material with a low level of viscosity. In a study evaluating the effect of viscosity, the low-viscosity fissure sealant had better penetration to enamel compared to high-viscosity fissure sealant.[33] On the other hand, viscosity does not affect the coating properties of fissure sealants.[34] Glass carbomer is a material that is highly adhesive and viscous, which makes it difficult for the material to penetrate the depths of the fissures. In addition, the material sets quickly, which may interfere with the ability of the material to reach the base of the entire fissure.[16] This phenomenon may explain the pitfalls of glass carbomer-based materials in our study. Similar results were seen when examining the ability of giomer and resin-based fissure sealants to maintain edge integrity in Group 1. These results may be attributed to the higher resistance of both materials to occlusal forces compared to GIC-based fissure sealants. With occlusal forces, it is necessary for materials to have a high flexural strength to prevent permanent structural damage to of dental materials. In another study, Bis-GMA-containing materials were reported to be harder and therefore less flexible, while giomers were more resistant to mechanical stress because they do not contain Bis-GMA.[35]

Glass carbomer and GIC-based fissure sealant subgroups had the most unsuccessful edge integrity results in Group 2. Within Group 3, glass carbomer-based fissure sealant was the most unsuccessful subgroup in terms of its ability to maintain edge integrity. In a study by Menne-Happ et al., the authors compared the mechanical properties of RMGIC, GIC, and glass carbomer cement.[36] This study demonstrated that differences in chemical structure of the materials significantly affected both the microstructure and the mechanical properties of the materials. RMGICs have high flexural strength, while glass carbomers have a high Vickers hardness value and low flow value. Certain properties of RMGIC, including larger glass particles, less space structure, and a lower number of cracks, provide higher flexural strength to this material. Since glass carbomer has low flexural strength, this may explain its lower performance in our study.

The dissolution of the cement components may affect the structural integrity of the material.[16] In the other study, the solubility of the glass carbomer cement was evaluated by storing it in artificial saliva at pH = 4 and pH = 6. By the end of the 7th day, the weight of the glass carbomer cement increased. The researchers thought that this increase in weight was due to the bonding of water molecules to glass ions and polycarboxylic acid within the cement. This increased water absorption within the material reduced the structural integrity of the cement.[16]

Today, the need for restoration or repair of restorative materials often occurs due to edge leakage and related complications. Studies have shown that the microleakage of GIC-based fissure sealants are significantly higher than those of resin-based fissure sealants.[37] Within Group 1 and Group 3 of our study, the GIC subgroups were found to be less successful in maintaining edge coloring due to microleakages near the edges of the water-absorbing material. In our study, giomer and resin-based fissure sealants were found to be successful in terms of maintaining edge coloring. In a similar study, the retention rate of giomers in class V cavities was equal to that of RMGIC, where no surface coloring or edge coloring in the teeth existed. However, the surface properties of the giomers are superior to those of RMGIC.[38]

Ataol et al. also found that the occurrence of microleakages within giomer-based sealants was similar to that of the resin-based fissure sealants in their study.[39]

When evaluated for surface roughness, the least successful material in Group 1 was the GIC-based fissure sealant. In Group 2, the GIC and glass carbomer-based fissure sealant groups were the least successful. In Group 3, the glass carbomer-based fissure sealant was the least successful Group, followed by the GIC-based sealant Group. Several *in vitro* studies on GIC-based fissure sealants have found cracks on the surface of these materials, despite the fact that the surface protective agent applied to the material was kept in water.[40,41] The researchers stated that these cracks were the result of dehydration after the GIC finished setting, and these cracks increased microleakages.[40]

Similarly, Cehreli et al. observed cracks and broken lines on the surface and the interior of the glass carbomer cements.[17] Many studies have shown that the surface of giomers is less rough than that of GIC-based materials.[20] In our study, we measured the roughness of the tooth restoration using an AFM device, which has not been used for this purpose in previous studies. In this study, our sample count was limited since the surfaces we evaluated are not usually in standard molds.

Nevertheless, we achieved similar results with the data obtained from the AFM device and data obtained by visual and sound analysis. In regard to preventing surface roughness, the most successful material was the resin-based fissure sealants followed by the glass carbomer based fissure sealants. According to the surface coloring evaluation in Group 1, the most unsuccessful material was the GIC-based fissure sealant followed by the glass carbomer-based fissure sealant. In Groups 2 and 3, the material that was the least successful in maintaining the original surface coloration was the glass carbomer, followed by the GIC-based sealant. We think that cracks observed on the surface of both materials contributed to excessive water absorption, which threated the integrity of the material. In a study which paralleled our own findings, the color change observed in the GIC Group was much more pronounced than the color change observed in the giomer Group. The ability to resist color change was determined by exposing GIC and giomer samples to various colors present in food and beverages and observing the change in color.[42]

CONCLUSION

GIC and glass carbomer-based fissure sealants may be a useful alternative to resin-based fissure sealants, which are known to release residual monomers. The glass carbomer-based fissure sealants may be used as an alternative to resin, giomer, and GIC-based fissure sealants. However, the long-term success of the glass carbomer-based fissure sealant is still not known, and may be evaluated in future clinical trials.

CONFLICT OF INTEREST

The authors declare that three were no conflicts of interest related to this case report.

ACKNOWLEDGMENT

This study was supported by Akdeniz University Scientific Research Projects Coordination Unit.

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(Received February 8, 2019; Accepted April 23, 2019)