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RESEARCH ARTICLE

MARGINAL MICROLEAKAGE OF GLASS IONOMER BASED RESTORATIONS AFTER CONVENTIONAL CAVITY PREPARATION AND ER: YAG LASER IRRADIATION

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ABSTRACT

Purpose: Assessing the microleakage of glass ionomer restorations (GIC) prepared with both conventional and Er:YAG laser techniques in Class V cavities is the purpose of the study.
Material and Methods: Twenty teeth with Class V cavities (4mm wide, 3mm high, 3mm deep) were used. Cavities were prepared on the buccal and lingual surfaces of teeth which were randomly separated into four groups. Er:YAG laser was used to prepare cavities in Groups II and IV, conventionally diamond bur was used to prepare cavities in Groups I and III. Then, Groups I and II were restored with conventional GIC (Ketac Molar Easymix, 3MEspe, Seefeld, Germany) and high viscosity GIC with resin coating (EQUIA Fil, GC Dental Co., Tokyo, Japan) to restore Groups III and IV. Samples were stored in distilled water at 37°C for 24 hours before subjecting to thermo-cycling (500 cycles,5°C-55°C). In a chewing simulator, all teeth were exposed to 50.000 cycles. We used 0.5% aqueous basic fuchsin dye to stain the samples and sectioned them bucco-lingually. Scoring dye penetration was made under a stereomicroscope. The data were analyzed by Kruskal-Wallis One-Way ANOVA and Mann-Whitney U tests.
Results: While the highest microleakage scores were obtained in the group prepared with Er: YAG laser and restored with conventional GIC the lowest microleakage scores were obtained in the group prepared with Er:YAG laser and restored with high viscosity GIC. When cavities prepared with Er:YAG laser or conventional method were restored with high viscosity GIC, no statistically significant difference was found between them ($p > 0.05$).
Conclusion: High viscosity GIC can be preferred as a restorative material in the restorations of Class V cavities prepared using both conventional and Er:YAG lasers.

Keywords: glass ionomer, microleakage, high viscosity glass ionomer, Er:YAG laser

INTRODUCTION

Removal of caries is a routinely done procedure mechanically with rotary instruments. However, there are many side effects while using rotary instruments such as noise, pain, overheating in the pulp tissue, vibration, and discomfort (1,2). Besides the most expressed fears among the patients are the needs for an anesthetic needle and dental drills (3). Recently, laser irradiation has become more popular as a cavity preparation technique to overcome these stressors (3).

Laser irradiation can use as a suitable method together with adhesive restorations for minimally invasive preparations especially for pediatric dentistry and minimal invasive cavity preparation. Using dental lasers for cavity preparation or conditioning of enamel and dentin surfaces, has been growing up in vitro and in vivo studies (1,2). Varied types of lasers with different parameters have been used on dental hard tissues. Er: YAG laser systems have been improved for dental hard tissues in 1997. In parallel with, Er: YAG lasers were approved by Food and Drug Administration (FDA) for removal of caries, preparation of cavity, and laser etching of enamel (4). The most promising lasers are especially Erbium,Chromium:Yttrium-Scandium-Gallium-Garnet (Er,Cr: YSGG), and Erbium: Yttrium-Aluminum-Garnet (Er: YAG) for hard-tissue procedures. Er: YAG lasers have the highest absorption to water and a high affinity to hydroxyapatite because they have wavelength of 2940 nm (5). Later on, Er:Cr:YSGG laser was improved with a wavelength of 2790 nm for dental hard tissue procedures. The main advantages while using laser devices are minimal pulp injury and besides on of rough and irregular surfaces (2-4). Furthermore, preference for lasers over rotary instruments for cavity preparation eliminates the fear of anesthetic needles and the noise of dental drills. (6).

The mechanism of hard tissue laser systems is first, vaporizing the water and other dehydrated components in dental hard tissues. During this process, the internal pressure increases to the point that destructive explosions of minerals occur within the tissues. Finally, removed hard tissues are formed (7).

In clinical practice cervical lesions due to caries, erosion, or abrasion were commonly noticed. It is often a challenge to restore Class V cavities due to gingival fluid and bleeding. Frequently for Class V cavity restorations, the composite resin restorative materials have been preferred. But, the polymerization shrinkage, which can result in microleakage around the margins of a composite resin material, is one of the most important disadvantages (4).

Glass ionomer cements can be an alternative material to composite resins, which are currently in use since the 1960s (3). Moreover, these materials have many advantages such as the good ability of chemical bonding to tooth and containing fluoride ions in their structure (4,7). Through, the most important difference of GICs apart from other restorative materials is the ability to release fluoride ions to the oral environment. Also, these restorative materials have therapeutic effects on dental hard tissues. It is also proved clinically that GICs enhance the remineralization process while reducing the demineralization of enamel and dentin tissues (8). Besides these advantages, GICs have some disadvantages and clinical limitations such as prolonged setting time, dehydration during initial setting, and weak mechanical properties. Therefore light-cured resin-modified glass ionomers (RMGIs), resin-reinforced glass ionomers, and hybrid nano-ionomers were developed. However, when these restorative materials are also found to be insufficient in clinical practice, manufacturers have developed a novel type of glass ionomer material that has reinforced properties (9). Finally, high viscosity glass ionomer cements (HV-GICs) were introduced to the clinicians.

This newly developed GIC system consists of a highly viscous conventional GIC and it is advised to be used with a novel nanofilled coating material which protects the material against wearing in the oral environment (10). Compared to conventional glass ionomers, the physical, mechanical, and aesthetic properties of HV-GICs are further improved and are less sensitive to moisture (11). One of the main differences of HV-GICs from conventional glass ionomers is the ratio of the particles and particle size (12,13). Within respective indications and cavity sizes, HV-GICs can be an alternative restorative material instead of composite resins. According to the literatures, HV-GICs showed acceptable clinical performances in Class I and Class II restorations as in class V cavities, when compared with the composite resins (14-16).

The use of dental lasers has been demanded especially for children and adults who have dental phobia. In addition, glass ionomer cements are often preferred for the restoration of permanent teeth in both adults and children.

Since there are the limited number of studies in the literature investigating cavities prepared with Er: YAG laser and restored with conventional glass ionomer formulations in terms of microleakage, it was decided to carry out this study (5).

The null hypotheses tested were: 1) There would be no difference between HV-GICs and conventional glass ionomer cement when the cavities were prepared by laser. 2) There would be no difference between laser and conventional preparations when the cavities were restored with a conventional GIC (CGIC).

MATERIAL AND METHODS

All procedures performed after this study was approved by the Bezmialem Vakif University Ethics Committee (21/265-13.11.2018) and were carried out according to the ethical standards of the institutional and/or national research committee and the 1964 Helsinki Declaration and its subsequent amendments or comparable ethical standards.

Tooth Selection

Using the “G*Power statistical program (ver. 3.1.9.4; Foul and Erdfelder, 1998)”; when Type-1 error is 5%, the effect size is 0.2, and power is 95%, the sample size is at least 10 cavities per group were found (17). Thus, 40 cavities were obtained which were prepared on both buccal and lingual surfaces of 20 teeth. A total of 20 non-carious, non-erupted, non-functional human permanent third molars were used in this study. All teeth were scaled with scaling instruments to remove residual tissues and stored in distilled water at room temperature until the experiments.

Cavity Pre-operation and Restoration

The second author generated a random allocation sequence and assigned collected teeth to the study groups. According to the cavity preparation methods, teeth were randomly divided into two groups. Then these two groups were divided into two subgroups according to the restorative materials. In Group I and III cavities were conventionally prepared with a diamond bur and in Group II and IV, cavities were prepared by Er: YAG laser. Standard Class V cavities (4mm width, 3mm high, 3mm depth) were prepared on both buccal and lingual surfaces of each tooth. A periodontal probe was used for controlled the sizes of the cavities. The occlusal margins of Class V cavities were prepared on the enamel tissue and the cervical margins were located at 1.5 mm above the cemento-enamel junction (CEJ). The same operator was prepared and restored all cavities.

The experimental groups were as follows:

Group I: Class V cavities were prepared conventionally with a diamond bur+restored with a CGIC.

Group II: Class V cavities were prepared with Er: YAG laser+restored with a CGIC.

Group III: Class V cavities were prepared conventionally with a diamond bur+restored with a HV-GIC.

Group IV: Class V cavities were prepared with Er: YAG laser+restored with a HV-GIC.

In Group I and II, a conventional cavity preparation was made with a 008 round diamond bur (G&Z Instruments, Austria) under water cooling.

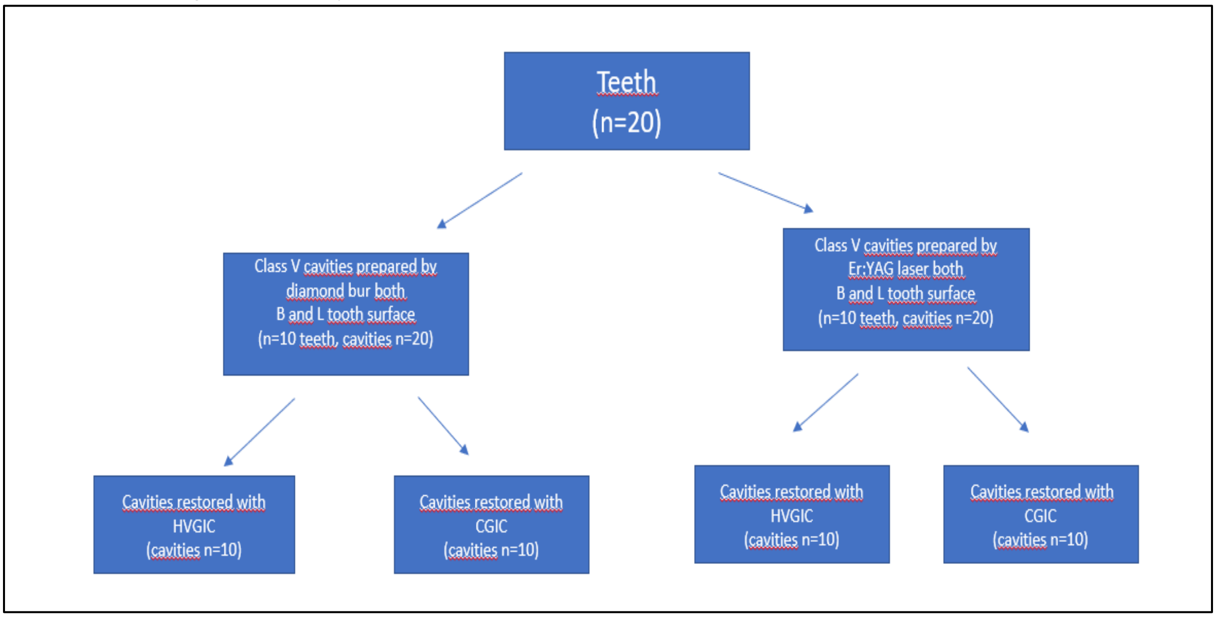
In Group III and IV, the teeth were prepared with Er: YAG laser (Fotona, Ljubljana, Slovenia) emitting a wavelength of 2940 nm with a non-contact mode under water spray coolant. The laser parameters used are 300 mJ and 20 Hz for enamel, 270 mJ, and 15 Hz for dentin structures and were determined by the manufacturer's recommendations (18).

In Group I and III, teeth were restored with a CGIC (Ketac Molar Easymix, 3M ESPE, Seefeld, Germany). In Group II and IV, teeth were restored with a capsulated HV-GIC (EQUIA Fil, GC Dental Co., Tokyo, Japan). After the restorations were completed, the teeth were polished with Sof-Lex discs (3M ESPE, St. Paul, MN, USA) from coarse to fine. For Groups II and IV which were restored with a HV-GIC, the coating material, (EQUIA Fil Coat, GC Dental Co., Tokyo, Japan) was applied on the surfaces according to the manufacturer’s recommendation and polymerized for 20 sec. with a LED light-curing unit (Valo, Ultradent, South Jordan, UT, USA.) to protect the restorations against staining, abrasion, wear, and mechanical forces. The study design was demonstrated in (Table 1). The materials used in this study are presented in (Table 2).

Storage and Thermo-Mechanical Aging Procedures

Afterward, all specimens were stored at 37°C for 24 hours and then were submitted to thermo-mechanical aging procedures. For the thermal cycling procedure, the teeth were subjected to 500 cycles (5-55°C) with a dwell time of 30 sec. and a transfer interval of 10sec. (SD Mechatronic, Germany). After these procedures were completed, samples were submitted to mechanical loading (SD Mechatronic Chewing Simulator CS 4-2, Germany) with 50.000 load cycles, at a frequency of 1,7 Hz to a vertical load of 50N on the restorations. During the mechanical loading test, the samples were submerged in distilled water.

Table 1. The design of the study



Microleakage Measurement

Microleakages scores were evaluated using a dye penetration technique. All the specimens were coated with two layers of transparent nail varnish, leaving a 1 mm window around the cavity margins. Subsequently, specimens were stained with 0.5% basic fuchsin dye (TEKKIM, Istanbul, Turkey) for 24 hours to produce a visible stain. Following the storage, the samples were rinsed under tap water, dried, and sectioned bucco-lingually with a water-cooled, slow-speed diamond blade (Mecatome T180, Presi, France). Microleakage was scored using a three-scale scoring system with a stereomicroscope (SMZ1000, Nikon, Japan) under x40 magnification (Table 3) (18).

Statistical Analyses

Descriptive statistics were calculated. The Shapiro Wilks test was performed for the test of normality. The non-parametric test was used because the microleakage values were not normally distributed. In each restorative material type (two levels: CGIC, HV-GIC) group, microleakage values comparisons between occlusal and gingival margins were analyzed using the Mann–Whitney U test. In addition, each cavity preparation method for each restorative material type groups microleakage values comparisons between the occlusal and gingival margins was analyzed using the Mann–Whitney U test. Kruskal–Wallis test was used to analyze the statistical differences in the mean microleakage values among the groups. When a significant difference was observed ($p<0.05$), the Kruskal Wallis One-Way ANOVA was used for multiple comparisons (19). All statistical analyses were performed using SPSS 20.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

Microleakage scores and median (min-max) values are shown in (Table 4).

Table 2. The type, manufacturer, and compositions of the materials used in the study

Material	Type	Manufacturer	Composition
Equia Fil	High viscosity glass ionomer cement	GC, Tokyo, Japan	Powder: 95% strontium fluoroalumino silicate glass, Liquid: 5% polyacrylic acid
Equia Coat	Nanofilled surface coating resin	GC, Tokyo, Japan	50 % Methyl methacrylate, 0.09 % camphorquinone
Ketac Molar	Conventional glass ionomer cement	3M ESPE, USA	Powder: Aluminium-calcium-lanthanum-fluoroisilicate glass Liquid: Polycarbonate acid

Table 3. Dye penetration scores used in the study

Dye Penetration Scores
Score 0: no leakage
Score 1: dye penetration to the enamel or cementum aspect of the preparation wall
Score 2: dye penetration to the dentin aspect of the preparation wall, but not including the pulpal wall
Score 3: dye penetration including the pulpal wall of the preparation

Table 4. Microleakage scores of the groups according to occlusal and gingival margins

Groups	Occlusal Margin				Gingival Margin				Occlusal Margin	Gingival Margin
	0	1	2	3	0	1	2	3	Median (Min-Max)	Median (Min-Max)
Group I (prepared conventionally + restored with a conventional GIC)	3 17,6 %	9 52,9 %	4 23,5 %	1 5,8 %	3 17,6 %	8 47 %	5 29, 4%	1 5,8 %	1 (0-3)	1 (0-3)
Group II (prepared with Er: YAG laser+ restored with a conventional GIC)	0 -	0 -	3 17,6 %	14 82, 3%	0 -	2 11, 7%	2 11, 7%	13 76, 4%	3 (2-3)	3 (1-3)
Group III (prepared with conventionally + restored with a high viscosity GIC)	7 41,1 7%	1 5,8%	2 11,7 %	7 41, 17 %	5 29,4 %	7 41, 17 %	2 11, 7%	3 17, 6%	2 (0-3)	1 (0-3)
Group IV (prepared with Er: YAG laser+ restored with a high viscosity GIC)	8 47%	4 23,5 %	2 11,7 %	3 17, 6%	6 35,2 %	4 23, 5%	2 11, 7%	5 29, 4%	1 (0-3)	1 (0-3)

When compared restorative materials in terms of with the Er: YAG laser preparation method HV-GIC showed a significantly lower degree of occlusal and gingival microleakage than CGIC (Group II vs Group IV) (p=0.000) (Table 4).
However, when the conventional bur prepared method was used there was no significant difference in the occlusal and gingival microleakage in the teeth restored with CGIC and HV-GIC (Group I vs Group III) (p=1.000) (Table 5).
According to cavity preparation methods revealed that for the teeth restored with CGIC, there was a statistically significant difference of the microleakage on occlusal and gingival margins between the conventional bur and laser preparation methods (Group I vs Group II) (p=0.000) (Table 4).
In terms of cavity preparation methods, no statistically significant difference was observed between occlusal and gingival microleakage values in teeth prepared with Er: YAG laser and conventional diamond bur and all restored with HV-GIC. (Group III vs Group IV) (p=1.000) (Table 5).

DISCUSSION

In this study, the microleakage of conventional diamond bur and Er: YAG laser prepared Class V cavities, restored with a conventional and a high viscosity glass ionomer material were evaluated. The highest microleakage value was obtained in a group which irradiated by Er: YAG laser and restored with CGICs. Therefore, the first null hypothesis was partially rejected. On the other hand, the lowest microleakage value was obtained in a group irradiated by Er: YAG laser and restored with HV-GIC. A statistically significant difference was obtained in groups restored with CGICs for each cavity preparation method. Based on these results, the second hypothesis was rejected.
Studies have shown that altering the surfaces of the teeth by lasers improves the adhesion of the restorations (20-22). In addition, there is little information in the literature about the sealing ability of Class V cavities prepared with Er: YAG laser and restored with CGICs. This limited information is probably due to the critical setting properties of GICs

(23). Therefore, this in vitro study was undertaken to evaluate the use of Er: YAG laser as an alternative to conventional diamond bur for the Class V cavities whether restored with a HV-GIC material or a CGIC material.

Table 5. Pairwise comparison of groups concerning microleakage (p<0.05).

Groups	***p*-value**
Group I vs **Group II**	0,000
Group I vs **Group III**	1,000
Group I vs **Group IV**	1,000
Group II vs **Group III**	0,008
Group II vs **Group IV**	0,000
Group III vs **Group IV**	1,000

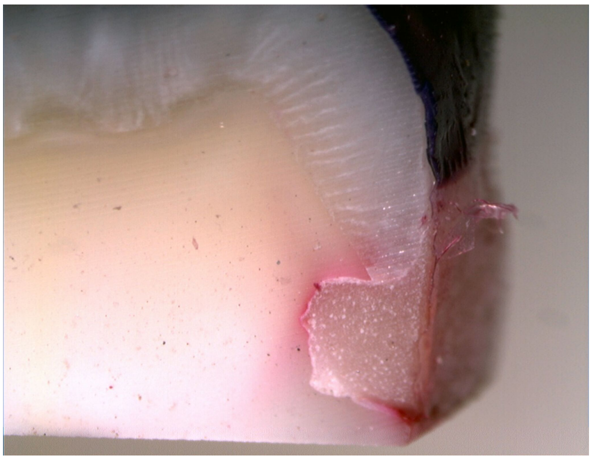


Figure 1. Representative microscopic image of the tooth of Group II with score 3 both occlusal and gingival margins

Microleakage is defined as a gap between the cavity wall and the restorative material (24). This gap can cause hypersensitivity, tooth discoloration, seconder caries, pulpal injury, and deterioration of the restoration (25,26). It is known that thermal expansion coefficient differences between dental tissues and restorative materials may cause microleakage. Therefore, the clinician's desire is; to choose a restorative with a similar coefficient of thermal expansion of dental tissues to reduce leakage at the margins of the restorations (27).

Microleakage is one of the most frequently encountered problems particularly in Class V restorations (3). This could be due to the location of Class V cavities frequently positioned below the cemento-enamel junction. Studies have shown that microleakage was higher at gingival walls of dentin or cement tissues than the occlusal walls of enamel tissue (6,18). However, in this study, occlusal margins of Class V cavities were prepared on the enamel tissue and the cervical margins were located at 1.5 mm above the cementoenamel junction (CEJ) in all groups. Therefore, in the results of the current study, there were no statistically significant differences between occlusal and cervical margins when the conventional bur prepared method was used and restored with CGIC and HV-GIC (Group I vs Group III) (p=1.000) (Table 5). Unlike the findings of our study, Bollu et al., in their study, reported that they observed more microleakage in the gingival margin than in the occlusal margin because they prepared the gingival margin on the cementum.

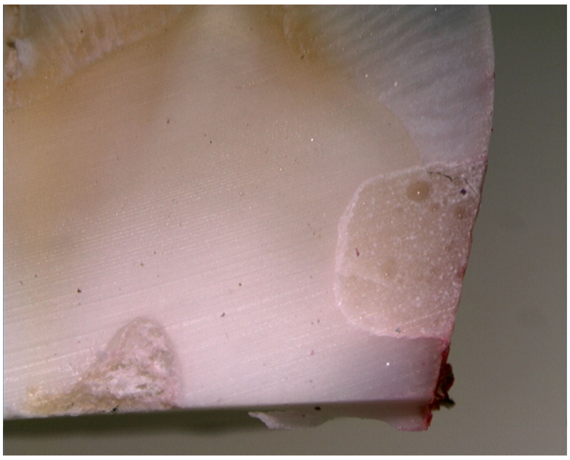


Figure 2. Representative microscopic image of the tooth of Group IV with a score 0 on the occlusal margin and score 1 on the gingival margin

Another result of this study is the highest microleakage scores observed in cavities prepared with Er: YAG laser and restored with CGIC (Figure 1). Even though, no statistically significant differences were found between the groups restored with high viscosity, the lowest microleakage scores were observed in prepared with Er: YAG laser and restored with high viscosity GIC (Figure 2). On the contrary of our study findings, Sertac et al. (28) reported that conventional glass ionomer cement presented less microleakage in the laser group compared to bur treatment. Besides, they reported that HV-GIC did not benefit from laser treatment and presented even increased microleakage. The difference between the results may occur that chemically based GIC was used in this study. Sertac et al. applied a cavity conditioner before placed the restorative material and used encapsulated CIS in their study.

Another reason is that low microleakage scores in laser-treated teeth may be associated with post-irradiation dentin morphology. It has been reported that the surface ablated with Er: YAG laser irradiation is devoid of a smear layer, and the dentinal tubules show a scaled intertubular region that increases the exposed intertubular dentin area. (21). Further studies are needed to investigate the morphological changes on enamel and dentin after the application of glass ionomer cement to laser-treated surfaces. Considering the distinctive topography produced by laser interactions with dental tissues such as dentin and enamel, it is probable that the surface modifications generated by laser irradiation may affect the chemical adhesion to dental tissue of glass ionomer cement. This may be the reason for the difference in microleakage between the laser-prepared group and the bur-prepared and subsequently restored by CGIC. As a matter of fact, in a study, it was reported that surface changes such as both macro and micro-roughness of enamel and dentin after Er, Cr: YSGG laser irradiation showed micro irregularities in both tissues and there was no smear layer (21). Laser-induced changes in the surface texture of enamel and dentin can potentially affect the microleakage of adhesive restorative materials (29).

The bonding mechanism of glass ionomer cements is chemical which is between the carboxyl group of cement and calcium ions of tooth structure. In recent studies, glass ionomer materials have better marginal sealing with enamel surface when compared to dentin surface (5,8). Although these materials have the advantage of chemical adhesion to the tooth surface, the mechanical adhesion of this material is unfortunately limited. Mechanical adhesion could only be achieved by plugging the material into the irregular surface of dentin tubules which were created by laser irradiation or burs. According to the results of this in vitro study, Class V cavities prepared with Er: YAG laser and restored with conventional GIC material showed the highest microleakage value at both occlusal and gingival margins. This result can be attributed to the poor sealing ability of the conventional glass ionomer cement. Like our study, Ali Baghlian et al. (30) reported that the teeth prepared by Er: YAG laser irradiation and restored with GI or RMGI were shown a higher degree of microleakage only at the gingival margin. Adhesion of glass ionomer cement to dental structures may be adversely affected (Fig 1) by dehydration caused by laser irradiation (9).

It should be considered that number of factors, such as moistening of the evaporated dentin during irradiation, changes in the chemical composition of the tooth structure, and irregular contours of the cavity margins may affect microleakage during Er: YAG laser preparation (3,9).

Although the content of HV-GIC material (EQUIA Fil) is based on the feature of glass ionomer technology, no statistical difference was observed when the teeth were prepared with either laser or conventional bur method and restored with HV-GIC. This could be due to the viscosity of the material. EQUIA Fil has been identified as a high viscosity conventional glass ionomer cement (31). It is known that this material has a high ratio of powder/liquid which provides stronger physical properties when compared with the conventional glass ionomer.

CONCLUSION

Based on these results, it may be concluded that clinicians can use high viscosity glass ionomer material with both Er: YAG laser and conventional bur cavity preparation method in Class V cavities safely.

Conventional glass ionomer material can be safely used in Class V cavities when the cavities were prepared with the conventional technique, rather than Er: YAG laser.

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Author contribution: Designed and performed the experiments: Z.B.K., N.D; Writing: Z.B.K, Review and Editing: S.S.H

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