

# Effect of Cements at Different Temperatures on the Clinical Performance and Marginal Adaptation of Inlay-Onlay Restorations In Vivo

Şeyda Aygün Emiroğlu, DDS, PhD, Buket Evren, DDS, PhD, & Yasemin Kulak Özkan, DDS, PhD

Department of Prosthetic Dentistry, University of Marmara, Istanbul, Turkey

## Keywords

Preheating; self-adhesive; SEM; inlay; onlay; clinical trial.

## Correspondence

Şeyda Aygün Emiroğlu, Marmara University, Faculty of Dentistry, Department of Prosthodontics, Büyükdik Sokak, No: 6 Güzelbahçe, 34365, Nişantaşı, Istanbul, Turkey. E-mail: seydaaygun@gmail.com

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## Abstract

**Purpose:** To evaluate the clinical performance of inlays and onlays luted with two different resin cements, mixed at different temperatures and to evaluate the marginal adaptation of the restorations.

**Materials and Methods:** One hundred IPS e.max restorations (82 onlays, 18 inlays; 84 molars, 16 premolars) were placed in 50 patients (28 females, 22 males, mean age, 33 years). The restorations were assigned to six groups according to the luting agent temperature (25°C, 37°C, and 54°C) and cement type (Variolink N high viscosity or G-Cem Automix). All restorations were evaluated after 1 week and 1 year by two examiners using modified USPHS criteria. Replicas of 30 selected onlay restorations (5 per group) were assessed for marginal quality under a scanning electron microscope (SEM) at 200×. Marginal adaptation was quantitatively evaluated in terms of percentage of gap formation, and marginal gap width was measured.

**Results:** After 1 year, the total survival rates of the Variolink N high viscosity group and G-Cem Automix group were 100% and 93.8%, respectively. Three debondings occurred with the G-Cem Automix group, one from each temperature group. For 1-year clinical service time, no significant difference was noticed in the marginal adaptation of Variolink N high viscosity groups and the 37°C G-Cem Automix group, while 25°C and 54°C G-Cem Automix groups' marginal adaptation scores decreased ( $p < 0.05$ ). Regarding the SEM evaluations, Variolink N high viscosity cement groups showed better marginal adaptation than G-Cem Automix cement groups ( $p < 0.05$ ). Cementation with the cements preheated to 37°C increased continuous margins in both enamel–cement and cement–ceramic interfaces, but these results were not statistically significant ( $p > 0.05$ ). Cements at different temperatures did not have significant effects on marginal gap widths of the restorations.

**Conclusions:** The restorations cemented with Variolink N high viscosity cement mixed at the three tested temperatures exhibited better treatment options than the self-adhesive groups. Preheating the self-adhesive cement (G-Cem Automix) to 37°C can be an effective method to have better marginal adaptation than the other self-adhesive groups (25°C, 54°C) tested in this study.

In the last decade, simplification of adhesive procedures in restorative dentistry has gained in importance.<sup>1,2</sup> Classical methods for luting ceramic restorations based on enamel/dentin adhesives are regarded as technique-sensitive and time-consuming, as they require multiple steps for application.<sup>2,3</sup> Self-adhesive resin cements have been introduced for adhesive luting of inlays, onlays, and posts.<sup>4,5</sup> Their popularity among dentists is based on the simplified application technique, since they do not require any pretreatment of the tooth substrate.<sup>1-3,6-8</sup> Also, self-adhesive resin cement use is associated with a reduction in postoperative sensitivity.<sup>9</sup> However, a limited etching

potential and the ability to only superficially interact with dentin have been observed for these cements.<sup>10-13</sup> It has been shown that self-adhesive resin cements are unable to develop a distinct hybrid layer,<sup>4,6,10,14</sup> related to the high viscosity of the cement that hinders deeper resin penetration.<sup>12</sup>

Evidence has shown that viscosity of resin composites can be decreased, and their flowability can be improved by preheating restorative resin composites.<sup>15,16</sup> It seems sensible to verify whether similar changes in the flow properties could be induced in resin luting agents, possibly improving marginal adaptation and interfacial strength.<sup>5</sup>

Beside viscosity, temperature has shown a strong positive correlation with monomer conversion. It has been demonstrated *in vitro* that preheated composites require less light exposure to achieve higher conversion values compared to room temperature photopolymerization.<sup>17</sup> By achieving higher final monomer conversion values, the amount of residual unreacted monomer, which may potentially leach into the oral cavity, is also reduced.<sup>17</sup> Moreover, as a result of enhanced conversion, preheating composite resins has been claimed to positively affect properties such as surface hardness, flexural strength, flexural modulus, fracture toughness, tensile strength,<sup>15,16</sup> and wear resistance.<sup>18</sup> These improved properties are also clinically relevant for luting materials; however, heating degree of resin composite is of great importance. Elsayad<sup>19</sup> reported curing composite resin at 68°C provided detrimental effects on the integrity of the resin/tooth interfacial bond. Cantoro *et al*<sup>4,5</sup> reported that it could be impossible to use dual-cured resin cements at very high temperatures because of the decreased working time.

Marginal integrity and bonding effectiveness have been reported to be the most important factors affecting restoration longevity.<sup>3,20-24</sup> The deterioration of marginal adaptation over time has been a common problem for all adhesively inserted restorations made of either composite resin or ceramic.<sup>25,26</sup> The marginal deterioration reported as the weak link for ceramic and resin composite inlays has been attributed to degradation of the luting cement.<sup>26-29</sup> In this study, marginal adaptation was characterized with scanning electron microscopy (SEM). SEM has been a generally accepted test method for examining the marginal morphology of dental restorations and for detecting marginal defects.<sup>30-33</sup> Gap-free/continuous cement margins have been considered important for longevity of dental restorations, even though continuous margins provide optimum connection for the best opportunity to minimize microleakage.<sup>31,34</sup> Marginal and internal accuracy of fit is also valued as an important criteria for cement dissolution.<sup>35,36</sup>

Therefore, the purpose of this study was to assess the clinical performance and the marginal adaptation of inlays and onlays luted with self-adhesive resin cement, which was tested in comparison with an etch-rinse cement considered to be the control.

## Materials and methods

Fifty healthy adult patients (28 women/22 men; 18–45 years) in need of esthetic posterior restorations were selected for this study. They met the following criteria: absence of pain and pulpal disease in the tooth to be restored, could tolerate applications of rubber dams, no signs of bruxism or clenching, high level of oral hygiene, normal proximal contacts and presence of antagonist teeth or fixed restorations in the opposing arch. All patients were treated at the Prosthodontics Department of Marmara University, Faculty of Dentistry, Istanbul, Turkey. The study was carried out according to research norms and guidelines for humans and was approved by the ethics committee.

The study sample included 100 e.max Press (Ivoclar, Vivadent, Schaan, Liechtenstein) restorations; 82 onlays, 18 inlays, cemented in 84 molars and 16 premolars. The restorations

were assigned to six groups according to the luting agent temperature (25°C, 37°C, and 54°C) and cement (Variolink N high viscosity [Ivoclar Vivadent, Schaan, Liechtenstein] and G-Cem Automix [GC, Tokyo, Japan]).

The preparations for the restorations were performed to diverge slightly without beveling the margins; 80- $\mu$ m diamond burs were used. The preparations were finished with 25- $\mu$ m finishing diamonds (Inlay Preparation Set 4363; Kommet, Lemgo, Germany). The restorations had a minimum thickness of 1.5 mm and a minimum width of 2 mm at the isthmus with rounded occluso-axial angles. No lining material was used; dentin close to the pulp was covered with spots of calcium hydroxide cement (Dycal, Dentsply, Milford, DE). For all preparations, the interim prostheses were made using Clip F (Voco, Cuxhaven, Germany) and cemented with calcium hydroxide cement. Full-arch impressions were made using a poly(vinyl siloxane) impression material (Elite P&P; Zhermack, Rovigo, Italy).

The preparations were made by one operator, and all restorations were fabricated in accordance with the manufacturer's instructions in the same commercial laboratory by the same technician. At the try-in of the restorations, anatomical form, marginal adaptation, and color were evaluated. Later, the internal surfaces of the ceramic restorations were etched with 5% hydrofluoric acid (IPS Etching Gel; Ivoclar Vivadent) for 20 seconds, rinsed, and then silanated with Monobond S (Ivoclar Vivadent). After application of the silane coupling agent, the solvent was evaporated with compressed air. Unfilled resin (Heliobond; Ivoclar Vivadent) was applied to the internal surface of the IPS e.max restorations.

The preparations were isolated against moisture with rubber dams. In the Variolink group, enamel margins were etched with 37% phosphoric acid gel (Etch37; Bisco, Schaumburg, IL) for 30 seconds, dentin surfaces for 15 seconds, and then rinsed for 30 seconds. Syntac Classic (Ivoclar Vivadent) was applied per manufacturer's recommendations (primer 15 seconds, adhesive 10 seconds, Heliobond applied and dispersed in a thin layer). In the G-Cem group, cement was applied onto slightly moist dentin surfaces following manufacturer's instructions without any other pretreatment of tooth hard tissues.

The resin cements were applied at 25°C or were heated to 37°C or 54°C prior to use with the preheating method used in previous studies.<sup>37-39</sup> For experimental groups, base and catalyst pastes were equally dispensed on a glass plate laying on a heating stirrer surface (C-MAG HS 7; IKAMAG, Staufen, Germany) previously set to 37°C and 54°C. Cement and glass plate temperatures were continuously measured using the K-type thermocouple of the heating stirrer to ensure that both pastes reached 37°C and 54°C. Based on the temperature control as measured using the thermocouple, it took approximately 30 to 40 seconds for the base and catalyst pastes to reach the desired temperature. Subsequently catalyst and base were mixed on the stirrer surface and applied to the restorations. The restorations were inserted with moderate pressure, and excess luting agent was carefully removed with an explorer. Under slight pressure, the restorations were light cured by a light-activating unit (Optilux 501; Demetron Kerr, Danbury, CT) for 40 seconds (Variolink) or 20 seconds

**Table 1** Modified USPHS criteria used

Modified criteria	Description	Analogous USPHS criteria
Excellent = alpha1	Perfect	Alpha
Good = alpha2	Slight deviations from ideal performance, correction possible without damage of tooth or restoration	Alpha
Sufficient	Few defects, correction impossible without damage of tooth or restoration; no negative effects expected	Bravo
Insufficient	Severe defects, prophylactic removal for prevention of severe failures	Charlie
Poor	Immediate replacement necessary	Delta

(G-Cem) from each margin. After polymerization, the rubber dam and overhangs were removed. Finally the occlusion was carefully checked, and the restorations were polished with Sof-Lex disc system (3M ESPE, Seefeld, Germany) and diamond polishing set (Brinell; Renfert, Hilzingen, Germany).

Recalls were performed at 1 week and 1 year after cementation using modified United States Public Health Service (USPHS) criteria (Table 1) by two advanced investigators using mirrors, probes, dental tape, and bitewing radiographs. The following clinical parameters were examined: marginal integrity, marginal discoloration, color match, anatomic form, secondary caries, surface roughness, tooth integrity, and restoration integrity. Photographs were taken before restoration, after preparation, and at 1 year (Figs 1, 2).

For the marginal quality evaluation with SEM, 30 extensive onlay restorations on 16 patients were selected (five cases from each of the six groups). All of the evaluated restorations had buccal margins located above the CEJ in enamel.

The surfaces were cleaned with a 5% NaOCl solution and washed with water. Impressions were made with PVS impression material (Elite P&P; Zhermack) 1 week and 1 year after cementation, and epoxy resin replicas were prepared. The replicas were mounted on aluminum stubs, sputter coated with gold, and examined under SEM (Jeol JSM-5910LV; JEOL Ltd, Tokyo, Japan) at 200× magnification. SEM examinations were performed by one operator with quantitative margin analysis.<sup>30</sup> The marginal integrity between the ceramic/cement interface and the enamel/cement interface was expressed as a percentage of the entire judgeable margin length. Marginal qualities were classified according to the criteria “continuous/gap free margin” and “gap irregularity.” Nonjudgeable parts and artifacts were excluded. Afterwards, the percentage of “continuous margin” in relation to the individual judgeable margin was calculated as marginal integrity.

Only buccal margins above the CEJ were analyzed quantitatively. For technical reasons gingivo-proximal areas could not be evaluated; lingual margins were excluded from the evaluation, since some were subgingival.

Cement width was measured directly on the screen using a calibrated electronic measuring bar at 100-μm increments on buccal margins. The mean marginal gap width was calculated for each specimen; this value was used to determine the mean marginal gap width for each group.<sup>40</sup> SPSS v17.0 for Windows software (SPSS Inc, Chicago, IL) was used to perform the statistical analysis.

## Results

### Clinical evaluation

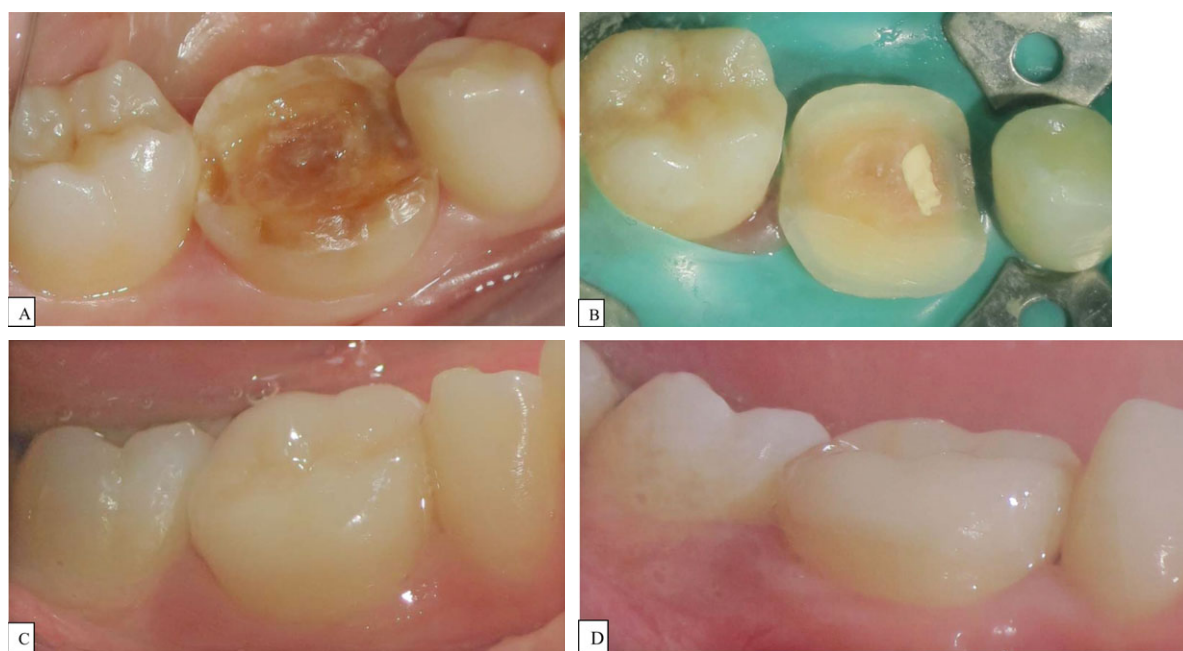
The results of the baseline and 1-year evaluations are presented in Table 2. After 1 year of clinical service, three restorations of the G-Cem cement group luted with different temperatures (25°C, 37°C, and 54°C) had to be replaced due to loss of retention and were excluded. Ninety-seven restorations were in satisfactory condition (survival rate computed with the Kaplan-Meier algorithm, 97%). The survival rate was 100% for the Variolink group and 93.8% for G-Cem group. Regarding survival rates, there was no significant difference between both groups (Log Rank test;  $p > 0.05$ ).

Over the observation period, restorations of the Variolink and G-Cem groups showed no statistically significant differences regarding inlay integrity, tooth integrity, secondary caries, anatomical form, surface roughness, and color match between baseline and 1-year (Chi-Square test;  $p > 0.05$ ). Statistically significant changes were observed for marginal adaptation and marginal discoloration between Variolink and G-Cem cements (Chi-Square test;  $p < 0.05$ ).

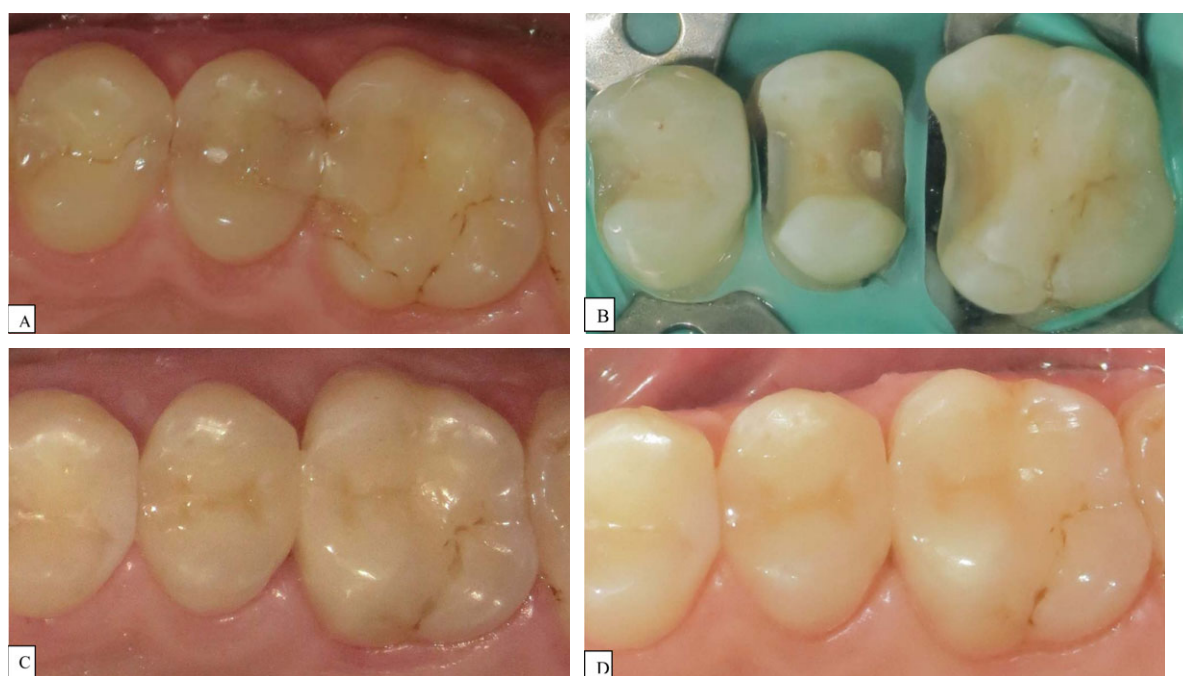
The percentage of restorations with excellent marginal adaptation (alpha 1) decreased from 100% to 96% for Variolink and from 100% to 53.3% for G-Cem after 1 year. Regarding the temperature groups, while 25°C G-Cem group (100% to 41%) and 54°C G-Cem group (100% to 38%) showed statistically significant decreases of alpha 1 values for marginal adaptation between baseline and 1 year, 37°C G-Cem group (100% to 81%) showed better results. Unacceptable scores (3 delta scores) were noted for the three failed restorations mentioned above. All other restorations showed clinically acceptable marginal adaptations. Significantly increased marginal discoloration was observed for the 25°C G-Cem group between baseline and 1 year. No esthetic failures, such as clinically unacceptable color mismatch, were present at the baseline and 1-year recall; only a slight difference in the percentage of restorations with alpha 1 and alpha 2 was noticed.

### SEM evaluation

The results of the quantitative marginal quality evaluations are summarized in Table 3. Representative SEM images of a restoration after 1 year in situ are shown in Figure 3. There was a statistically significant ( $p < 0.05$ ) difference of the percentage of continuous margins both at the ceramic/cement and



**Figure 1** Variolink: (A) baseline; (B) preparation; (C) 1 week; (D) 1 year.



**Figure 2** G-Cem Automix: (A) baseline; (B) preparation; (C) 1 week; (D) 1 year.

enamel/cement interfaces between the baseline and 1-year recall as calculated with the Wilcoxon signed rank test. Percentages of continuous margins for both ceramic/cement and enamel/cement interfaces decreased over time.

Continuous margin percentages of Variolink and G-Cem resin cements were compared both on the ceramic/cement and

enamel/cement interfaces. Variolink cement groups resulted in significantly higher percentages of continuous margins than G-Cem cement groups (Mann-Whitney U test;  $p < 0.05$ ) (Table 4).

Preheating of Variolink and G-Cem resin cements did not enhance the percentage of the continuous margins as calculated with the Kruskal Wallis test (Table 5) ( $p > 0.05$ ), but the largest



**Table 2** Result at baseline and 1 year after placement in relation to modified USPHS criteria

	Baseline								1-year							
	Variolink				G-Cem				Variolink				G-Cem			
	25°C	37°C	54°C	Total	25°C	37°C	54°C	Total	25 °C	37°C	54°C	Total	25°C	37°C	54°C	Total
Marginal integrity																
Alpha 1	100	100	100	100	100 <sup>a</sup>	100	100 <sup>b</sup>	100 <sup>c</sup>	94	94	100	96	41 <sup>a</sup>	81	38 <sup>b</sup>	53.3 <sup>c</sup>
Alpha 2	0	0	0	0	0	0	0	0	6	6	0	4	53 <sup>a</sup>	13	56 <sup>b</sup>	40.7 <sup>c</sup>
Delta	0	0	0	0	0	0	0	0	0	0	0	0	6 <sup>a</sup>	6	6 <sup>b</sup>	6 <sup>c</sup>
Marginal discoloration																
Alpha 1	100	100	100	100	100 <sup>d</sup>	100	100	100	100	100	100	100	71 <sup>d</sup>	88	77	78.6
Alpha 2	0	0	0	0	0	0	0	0	0	0	0	0	29 <sup>d</sup>	12	23	21.4
Color match																
Alpha 1	70	83	75	76	59	63	37	53	65	83	75	74	53	63	31	49
Alpha 2	30	17	25	24	41	37	63	47	35	17	25	26	47	37	69	51
Anatomic form																
Alpha 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Secondary caries																
Alpha 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Surface roughness																
Alpha 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Tooth integrity																
Alpha 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Restoration integrity																
Alpha 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

<sup>a</sup>Significant difference between baseline and 1-year recall ( $p < 0.05$ ) (Wilcoxon signed rank test).

percentage of continuous margins was observed for the 37°C groups. The width of the luting cement in the buccal portion of the IPS e.max restorations is reported in Table 6. Mean cement width was measured as 124.13  $\mu\text{m}$  for Variolink and 126.13  $\mu\text{m}$  for G-Cem cement. No significant difference was found between Variolink and G-Cem cements (Mann-Whitney U test;  $p > 0.05$ ), or between the 6 temperature groups (Kruskal Wallis test;  $p > 0.05$ ). In this study, use of preheated resin cements did not change marginal gap width.

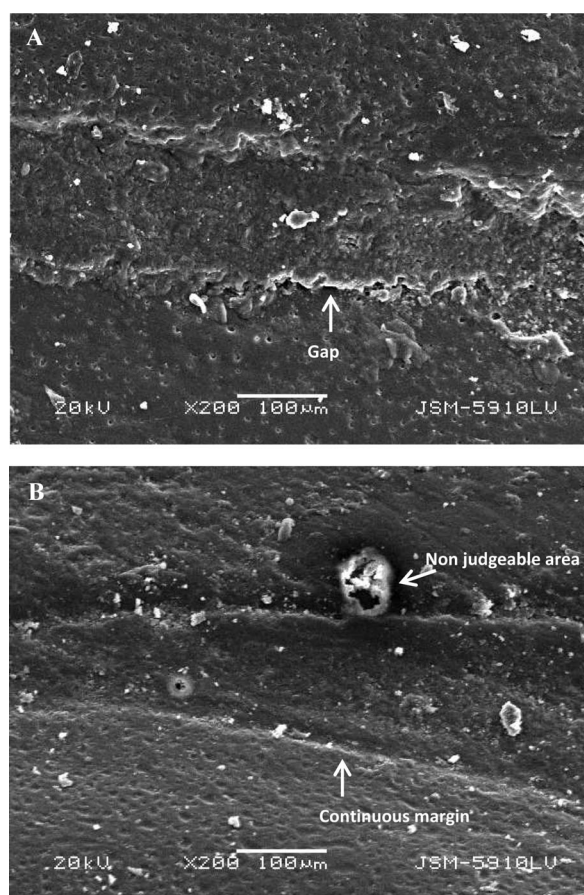
## Discussion

The clinical performance of adhesively bonded all-ceramic restorations has mostly been studied in short-term studies for ceramic inlays; only a few studies were found with extended observation times of 10 years.<sup>27</sup> The most commonly reported major clinical complications resulting in failure of all-ceramic restorations were the fracture of ceramic<sup>20,25,27</sup> and the decementation of restoration.<sup>25,27</sup> Guess *et al* reported a 100% survival rate of IPS e.max Press partial ceramic crowns over 28 months<sup>28</sup> and 7 years.<sup>29</sup> In this study, there was no ceramic fracture of the restorations for 1-year clinical service time, confirming the enhanced strength of IPS e.max.

Schenke *et al*<sup>2</sup> reported a 93.3% survival rate with three debondings at 2 years for glass ceramic partial crowns luted with RelyX Unicem, and Peumans *et al*<sup>3</sup> reported 5.1% failure rate with two debondings at 2 years. These results were similar to the results of this study in which no debondings occurred in the restorations luted with Variolink (100% survival rate),

while three debondings occurred in each temperature group of G-Cem (93.8% survival rate). In the literature, a superficial interaction with the dental substrate without the generation of a distinctive hybrid layer or resin tags was described for self-adhesive resin cements.<sup>4,10,14</sup> Cantoro *et al*<sup>6</sup> reported that RelyX Unicem and G-Cem cements both appeared densely filled with particles of relevant size and unable to penetrate into the dentin. Another factor contributing to mechanical properties was the presence of voids and porosities within G-Cem<sup>4</sup> and RelyX Unicem.<sup>10</sup> These factors might cause an insufficient adaptation of self-adhesive cements to the dental substrate.

The modified USPHS criteria proved to be reliable for tooth-colored restorations as previously reported.<sup>3,7</sup> In a clinical trial,<sup>3</sup> IPS Empress 2 inlays were luted with RelyX Unicem using selective enamel etching and nonetching. The nonetched group's marginal adaptation score decreased from 67% with excellent margin (alpha 1) to 20%. Following the same tendency, Taschner *et al*<sup>7</sup> reported that the nonetched group of RelyX Unicem decreased from 91% of alpha to 67%. Also, in a 1-year study comparing RelyX Unicem and Variolink II with modified USPHS criteria, Taschner *et al*<sup>1</sup> reported that marginal integrity was significantly better in the Variolink II group than in the RelyX Unicem group. In this study, as comparable with similar clinical studies, etch-rinse cements showed better marginal adaptation than self-adhesive cements. After 1 year of clinical service time, the marginal adaptation of Variolink groups and 37°C G-Cem group did not change statistically, while 25°C and 54°C G-Cem groups' marginal adaptation scores dropped from 100% alpha 1 to 41% and 38%, respectively.



**Figure 3** (A) SEM image of a restoration after 1 year in situ (B) SEM image of a restoration after 1 year in situ.

**Table 3** Percentages of continuous margins (%)

	Baseline Mean $\pm$ SD	1-year Mean $\pm$ SD	<i>p</i>
All restorations			
Ceramic-cement	93.2 $\pm$ 4.55	88.83 $\pm$ 5.52	<0.0001*
Enamel-cement	94.4 $\pm$ 4.34	91.2 $\pm$ 5.98	<0.0001*

\**p* < 0.05.

No *in vivo* study has evaluated the marginal quality of glass ceramic inlay-onlay restorations luted with self-adhesive resin cements under SEM. In an *in vitro* study, Frankenberger *et al*<sup>8</sup> reported initial continuous margins for IPS Empress inlays in enamel of 100% for Variolink, 91.4% for RelyX Unicem, and 96.9% for MaxCem; and after thermomechanical loading 96.3%, 69.8%, and 54.4%, respectively. The percentages of continuous margins in enamel for Variolink were similar to this study but the percentages of self-adhesive cements were lower; however, Aschenbrenner *et al*<sup>32</sup> and Behr *et al*<sup>33</sup> reported percentages of continuous margins similar to this study for self-adhesive cements. Frankenberger *et al*<sup>8</sup> also reported that etch-rinse systems resulted in higher percentages of gap-free margins in enamel than all other luting systems, which was confirmed in this study. The etch-rinse luting agent Variolink

**Table 4** Comparison of continuous margin percentages in terms of used cements

		Mean	SD	<i>p</i>
Ceramic-cement baseline	Variolink	95.80	2.96	0.001*
	G-Cem	90.60	4.45	
Ceramic-cement 1-year	Variolink	91.00	6.08	0.011*
	G-Cem	86.67	4.01	
Enamel-cement baseline	Variolink	97.27	2.46	<0.0010*
	G-Cem	91.53	3.93	
Enamel-cement 1-year	Variolink	95.20	3.28	<0.0001*
	G-Cem	87.20	5.40	

\**p* < 0.05.

**Table 5** Comparison of continuous margin percentages in terms of used temperatures (25°C, 37°C, and 54°C) with Kruskal-Wallis test

		Variolink			G-Cem		
		Mean (%)	SD	<i>p</i>	Mean (%)	SD	<i>p</i>
Ceramic-cement baseline	25°C	94.40	4.56	0.155	92.00	4.24	0.219
	37°C	97.60	1.52		91.80	3.63	
	54°C	95.40	0.89		88.00	5.05	
Ceramic-cement 1-year	25°C	86.80	8.04	0.166	84.20	3.96	0.169
	37°C	94.20	4.76		89.20	2.86	
	54°C	92.00	2.45		86.60	4.10	
Enamel-cement baseline	25°C	97.60	1.52	0.201	91.00	4.36	0.266
	37°C	98.60	1.34		93.80	3.19	
	54°C	95.60	3.36		89.80	3.77	
Enamel-cement 1-year	25°C	94.60	3.05	0.322	85.40	3.78	0.080
	37°C	97.20	1.92		91.40	4.51	
	54°C	93.80	4.09		84.80	5.85	

**Table 6** Mean widths of the luting cement in the vestibular portion of the IPS e.max onlays

	Mean ( $\mu$ m)	SD	<i>p</i>
25°C Variolink	110.40	28.88	0.456
37°C Variolink	134.40	28.69	
54°C Variolink	130.00	37.24	
25°C G-Cem	119.80	24.81	
37°C G-Cem	109.00	6.04	
54°C G-Cem	149.60	37.00	

achieved significantly better results than the self-adhesive luting agent G-Cem at any assessed precure temperature. Regarding the temperature groups, although no significant differences in terms of gap formation were detected, 37°C groups had the smallest mean value between both Variolink and G-Cem cement groups.

McLean and von Fraunhofer<sup>35</sup> and Fransson *et al*<sup>36</sup> have reported that clinically acceptable marginal gaps after cementation should be less than 150  $\mu$ m and 120  $\mu$ m, respectively. Mean marginal gap width values recorded in the literature for pressable ceramic inlay-onlay restorations were between 46

and 189  $\mu\text{m}$ .<sup>8,21-24</sup> Therefore, the results of this study (mean between 109 and 149.6  $\mu\text{m}$ ) are within biologically acceptable limits and are comparable with similar studies.

No significant difference was found between the study groups regarding the marginal gap width. The type of luting cement and pre-cure temperature did not lead to significant differences in the marginal gap width of IPS e.max onlay restorations.

In a recent study,<sup>37</sup> the working time of two commercial, dual-cured resin cements polymerized at varying temperatures were evaluated. Significant reduction in both Calibra and Variolink cements at 37°C led to nearly 70% reduction (Calibra 23 seconds, Variolink 95 seconds), and at 50°C a nearly 90% reduction (Calibra 10 seconds, Variolink 37 seconds) was observed. The authors reported that pre-heating of resin cements could make the material impossible to handle because it set so rapidly. Therefore it is recommended to avoid pre-heating of resin cements with a higher content of self-curing components, which was confirmed in this study.

In the studies in which cements were heated to 60°C, RelyX Unicem<sup>5</sup> and G-Cem<sup>4</sup> set during mixing. Moreover, Calibra and Multilink Sprint<sup>4</sup> were set even before the time of mixing. In this study, because of the decreased working time of 54°C for G-Cem, the results for both clinical evaluation and SEM observations were not as successful as expected.

Elsayad<sup>19</sup> reported that the use of preheated resin composite to 37°C might improve adaptation and decrease interfacial gaps, but when the composite resin was preheated to higher temperatures (i.e., 68°C), this caused tooth deformation and subsequently other clinical manifestations. Because of this deformation, the rapid photo-polymerization occurring at elevated temperatures was indicated. Elsayad reported that high reaction rates might lead to higher stress formation and might increase the amount of thermal contraction.

It has been reported that dual-curing resin cements in combination with conventional etch-rinse systems are considered to be the gold standard in luting ceramic inlays and onlays.<sup>9</sup> Regarding this study and the limited number of studies in the literature, it can be reported that it is useless to pre-heat dual-cured resin cements at high temperatures, since benzoyl peroxide accelerates the polymerization reaction and shortens the working time.

## Conclusion

According to the results of this study, the restorations cemented with etch-rinse cement mixed at the three tested temperatures exhibited better treatment results than the self-adhesive groups. Pre-heating the self-adhesive G-Cem cement to 37°C was an effective method to have better marginal adaptations than noted with the other self-adhesive groups. Clinical trials with longer observation periods would be advisable to confirm the data collected in this investigation.

## References

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