Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2022; 22:e210148
https://doi.org/10.1590/pboci.2022.064
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Evaluation of Microleakage at the Junction Between Combined Amalgam/Composite Resin Restorations Using Different Bonding Systems in Class II Cavities

Elham Zajkani[1], Fatemeh Omidi[2], Zahra Taromi[1]

[1]Department of Restorative Dentistry, Faculty of Dentistry, Zanjan University of Medical Sciences, Zanjan, Iran.
[2]Faculty of Dentistry, Zanjan University of Medical Sciences, Zanjan, Iran.

Correspondence: Elham Zajkani, Department of Restorative Dentistry, Faculty of Dentistry, Zanjan University of Medical Sciences, Zanjan, Iran. **E-mail:** elham.zajkanident@gmail.com

Academic Editor: Catarina Ribeiro Barros de Alencar

Received: 31 July 2021 / **Review:** 17 December 2021 / **Accepted:** 21 February 2022

How to cite: Zajkani E, Omidi F, Taromi Z. Evaluation of microleakage at the junction between combined amalgam/composite resin restorations using different bonding systems in Class II cavities. Pesqui Bras Odontopediatria Clín Integr. 2022; 22:e210148. https://doi.org/10.1590/pboci.2022.064

ABSTRACT
Objective: To evaluate the microleakage at the junction between amalgam-composite resin restorations using different bonding systems. **Material and Methods:** In this in-vitro study, standard class II cavities were prepared on 40 human maxillary premolars. The axial and gingival floor depths of the cavities were 2 mm and 1 mm below (cementoenamel junction), respectively. The samples were divided into 4 groups (n = 10). In all groups, a layer of 1-mm thick amalgam was used as a coating for the initial part of the gingival floor. In group 1, no bonding system was used for amalgam restoration. In group 2, G-Premio Bond was applied. G-Premio bond + alloy primer and single bond + alloy primer were used in group 3 and group 4, respectively. The rest of the cavities in all groups were then repaired using FiltekZ250 composite. The samples were thermocycled at 500 rpm and immersed in 1% methylene blue solution for 24 hours to allow dye penetration. Once cut, the samples were placed under a stereomicroscope (40X) to determine the microleakage rate. Data analysis was carried out using post-hoc and Chi-square tests ($p<0.05$). **Results:** The highest and lowest microleakage rate was related to groups 1 and 3, respectively. There was a significant difference between groups (1,2) and (1,3), and (1,4), and groups (2,3) ($p<0.05$). **Conclusion:** The use of alloy primer and bonding could reduce the microleakage between the two restorations.

Keywords: Dental Leakage; Dental Restoration, Permanent; Dental Amalgam; Dental Bonding.

Introduction

Composite resin restoration in cavities with gingival margins is a constant concern. Most margins are located in deep cavities below the CEJ (cemento-enamel junction) and on cementum and dentin under clinical conditions. Dentin bonding is difficult due to its heterogeneous nature and requires a bonding system that is compatible with hydroxyapatite, collagen, smear layer, dentin tubules, and dentin fluid at the same time [1]. Various strategies have been used to improve the marginal seal of materials, one of which is the use of combined restorations [2].

In the deep-margin composite resin restoration, resin-modified glass ionomers (RMGI) and amalgam lower the composite volume, reducing the c-factor and the stress caused by polymerization shrinkage in the composite [3].

The technique of using composite-amalgam on the gingival floor of the proximal CLII cavities can also be effective in inhibiting microleakage in this area [4]. This technique also enhances the fracture resistance of the cusps. It is stated that this technique creates a better contour and proximal contact and more retention than conventional amalgam or composite restoration [5].

One of the most important aspects related to the quality of amalgam/composite resin restorations is the quality of the surface bonding between amalgam and resin composite restorations [6]. Therefore, various techniques have been introduced for bonding composites to amalgam, most of which are based on mechanical and chemical purposes. After using 4-META (4-methacryloyloxyethy trimellitate anhydride) monomer-based adhesive systems for bonding composites to amalgam, this monomer is believed to be able to react with metals by forming unique bonds with metal oxides or formed amalgam-containing active metal components [7].

Among the various bonding systems, G-Premio contains 4-META and is used as a monomer. Many studies have reported that alloy primers are effective in bonding resin composites to metals. However, there has been no study on the effectiveness of this method in bonding composites to amalgam [8]. Furthermore, the literature review results revealed that there is no study on the use of composite restorations; only primers and mechanical methods and finally, adhesives of older generations have been used for some time, and there is a gap in this regard. There has been no specific and applicable method either, which leads to confusion among dentists in using the methods and materials.

The present study aimed to investigate the microleakage at the junction between amalgam/composite restoration using different bonding systems of G-Premio, Alloy primer and Single bond to compare and evaluate their performance and to find an acceptable standard solution to fill the gap in this type of research.

Material and Methods

Study Design and Ethical Clearance

In this *in vitro* study, 16 extracted, intact human maxillary premolars were examined as a pilot study to determine the total number of samples. Then, using the results of the pilot study, 40 intact human maxillary premolars were studied as the main samples. Study authorization was granted by the owner of the dental office, and only teeth extracted for orthodontic and periodontal reasons were included in the study, for ethical reasons (IR.ZUMS.REC.2018.248).

Data Collection

The collected teeth were carefully examined, and teeth with cracks, caries, and abnormalities were excluded from the study. After rinsing and removing excess tissues, the teeth were disinfected using chloramine

1% (Carl Roth GmbH + Co. KG, Karlsruhe, Germany) solution for one week and kept in physiological serum until the present study began. Afterward, the samples were mounted in a self-cure acrylic resin (Acropars, Marlic Co., Tehran, Iran). Next, class II cavities of the same size were prepared in all teeth using diamond fissure bur (D & G, Germany 0.8) along with water and air spraying. In the box, an occlusogingival height of 4- 5 mm, approximately 1 mm below the cemento-enamel junction (CEJ), buccolingual width of box cavities, and axial depth were 4 and 2 mm, respectively. Also, a new fissure bur was used after cutting all five cavities.

Then, the teeth were randomly divided into 4 groups (n = 10), and the restoration steps were performed as follows (Table 1).

Table 1. Application modes and descriptions of the materials.

Manufacture	Application Procedures	Composition	Material
GC Corp., Tokyo, Japan	The bonding layer was applied to all surfaces, and the tooth surface was dried with the highest intensity of air pressure for 5 seconds after a 10-second interval and cured for 20 seconds.	10-MDP, 4-META, MEPS, phosphoric acid ester monomer, dimethacrylate, acetone, silicon dioxide, initiators pH=1.5	G-Premio
3M ESPE, USA	The cut surface was impregnated with a bonding agent for 20 seconds. It was then air-dried for 5 seconds with gentle pressure and cured for 10 seconds.	Dimethacrylate	3M ESPE, USA
GC Corp., Tokyo, Japan	Apply the primer as a thin layer on the cut surface and wait for 5 seconds.	6-(4-vinybenzy-N-propyl)amino-13,5,-triazine-2,4-dithione (VBATDT), MDP, acetone.	Alloy primer
3M, ESPE, USA	The layers of maximum thickness of 2 mm were placed in the cavity and then cured for 20 seconds.	Inorganic filler (60% by volume) BIS-GMA, UDMA, and BIS-EMA resins.	Filtek Z250
Sinalux, Iran	One-unit amalgam was placed in the cavity after being mixed by the amalgamator for 13 seconds and condensed with the condenser depending on the cavity size.	Silver (42.6%), Tin (31.4%), Copper (26%)	Sinalux, Iran
South Ulteradent Jordan, USA	The surface of the cavity was dried with an air spray, and acid was applied to the cavity surface. The etching time for enamel and dentin was 15 seconds and brush the tooth surfaces for 15 seconds and then dry with gentle air pressure and cotton.	35%phosphoric acid solution	Etchant gel

- Group 1: Tofel Meyer holder and celluloid matrix tape should have been fastened and tightened around each of the teeth of this group. Then, a high-copper fast set layer of 1 mm thick amalgam (Sinalux, Faghihi Co., Tehran, Iran) was placed on the gingival margin of the cavity. Amalgam thickness was measured using a periodontal probe beyond the transparent celluloid matrix. A total of 10 minutes [5,8] was considered for the amalgam set. In this group, as a control group, no materials such as primer, bonding, and acid etching were used on the amalgam. Then, the remaining surface of the cavity was repaired with Filtek Z250 composite (A2 shade with 2-mm thick layers) and cured by a light curing device (Mectron S.P.A, Carrasco, Italy) with a minimum intensity of 700-1400 mW / cm^2 for 20 seconds.
- Group 2: Amalgam was applied similarly to the first group. Then, two layers of G-Premio bonding were applied to the amalgam surface (at a 10-second interval), where each layer was thinned with the intense air force for 5 seconds (according to the manufacturer's instructions) and cured using a light curing device. Next, the remaining surface of the cavity underwent resin composite restoration as with Group 1. After curing 5

samples, the output light intensity was evaluated by a radiometer (Starlight Pro, Mectron S.P.A, Carrasco, Italy).

- Group 3: The procedure was the same as Group 2, with the difference that alloy primer was used as a primer before placing the bonding in the cavity. Thus, the primer was placed as a thin layer in the cavity, and G - Premio bonding was applied similarly to Group 2 after 5 seconds.
- Group 4: Similar to Group 1, amalgam was applied, the cavity surface was dried, and 35% phosphoric acid was gently applied onto the surface of the remaining tooth walls by a micro-brush.

Etching was applied to enamel and dentin for 15 seconds, and then the tooth surfaces were rinsed for 15 seconds and dried with gentle air pressure and cotton. Afterward, an alloy primer was used as a primer. Specifically, the primer was placed as a thin layer on the amalgam in the cavity, and the single bond agent was applied in two layers after 5 seconds. It was then cured for 10 seconds, where the remaining surface of the cavity was restored, similar to Group 1.

Once the restorations were completed, the samples were stored in water at 37 °C and 100% humidity for 24 h prior to testing and then subjected to thermal cycles (500 cycles), 5 and 55 ° C each for 1 minute (each with 30 seconds and 10 breaks between two temperatures) (TC-300; Vafaei Industrial, Iran). The teeth were then covered with nail varnish except for the restoration area and 1 mm around it to avoid false positive results via dye penetration from another point rather than the restoration margins. Afterward, the samples were placed in 10% methylene blue solution (24 h). The teeth crowns were cut from the middle in the mesiodistal direction using the Mecatome device (T201A1, Presi France, Eybens, France) with water flow. Thereafter, dye penetration was examined by a stereomicroscope (x40) (Leica Microsystems GmbH, Wetzlar, Germany) to determine and compare the microleakage rate. The percentage of microleakage in the margins was quantitatively evaluated using standard degrees.

Table 2. The scoring system of the dye penetrations.

Degree	Dye Penetration Rate (Qualitative)	Dye Penetration Rate (Quantitatively)
0	No dye penetration	0 mm
1	Dye penetration is about half the cavity depth	0-1 mm
2	Dye penetration of more than half the cavity depth	1-2 mm
3	Dye penetration into the axial wall	2 mm

Data Analysis

Data analysis was carried out using post-hoc and Chi-square tests. Analyses were performed with IBM SPSS Statistics software version 20.0 (IBM Corp., Armonk, NY, USA) considering a 95% confidence interval.

Results

The microleakage was observed in all groups. However, the highest and lowest microleakage rate was related to groups 1 and 3, respectively. Table 3 reports the frequency and percentage of microleakage at the junction between amalgam and composite restorations in the four studied groups. A statistically significant difference between four groups in terms of microleakage percentage at the junction between the amalgam and composite restoration was observed ($p<0.001$).

The Post hoc test indicated a significant difference between groups (1 and 2), (1 and 3), (1 and 4) ($p<0.001$), as well as between groups (3 and 2) ($p= 0.001$) in terms of microleakage rate.

Table 3. Microleakage score in the four groups.

Groups	Degree				p-value
	0	1	2	3	
	N (%)	N (%)	N (%)	N (%)	
Group 1	0 (0.0)	1 (10.0)	4 (40.0)	5 (50.0)	<0.001
Group 2	0 (0.0)	8 (80.0)	2 (20.0)	0 (0.0)	
Group 3	6 (60.0)	4 (40.0)	0 (0.0)	0 (0.0)	
Group 4	2 (20.0)	7 (70.0)	1 (10.0)	0 (0.0)	

Discussion

The two major goals of restorative dentistry are to maintain function and to ensure teeth' beauty. Combined amalgam-composite restorations have advantages such as ensuring an acceptable level of beauty, increasing fracture resistance, as well as reducing the amount of cusp flexion and the treatment cost. However, concerns about problems and consequences such as post-treatment allergies and recurrence of caries have also increased due to the growing number of Class II deep composite resin repairs where the gingival floor of the cavity is located on the cementum and dentin [9].

According to the results, the highest microleakage rate was observed in the interfaces of amalgam-amalgam-composite restorations in group 1 (no primer and bonding between the two restorations, control group), group 2 (using G-Premio bond alone), group 4 (Alloy primer +single bond), and group 3 (Alloy primer +G-Premio bond).

Various conventional methods have been utilized for assessing marginal integrity *in vitro*. These include microscopic examination of a bonded specimen or its replica and dye penetration test. However, such methods are considered semi-quantitative, time-consuming, and possibly subjective [10]. On the other hand, non-invasive imaging methods include Optical coherence tomography (OCT), which has been introduced and employed for two-dimensional and three-dimensional evaluation of dental structures as well as biomaterials [11,12].

Many researchers have approved the effectiveness of amalcomp technique and amalgam as a base in reducing the microleakage rate in composite cavities [13].

Amalgam has a condensation property (it can be packed) and does not stick to the pen when placed in the cavity; thus, it adapts well to the cavity walls [4,14]. In addition, this material is stable over time, does not degrade, and has dimensional stability. This technique also induces the auto-sealing property of amalgam in response to surface corrosion, leading to oxide deposition, which can be used to sealing deep CLII cavities [15].

This happens over time and depends on the amount of oxides released from the amalgam during its corrosion. However, the amount of corrosion in high-copper amalgams is low. Further, unlike conventional composites, there is no mechanical or chemical bond between the tooth and the amalgam in RMGI and flow composites, and the seal only depends on a good amalgam-tooth adaptation [16].

Consistent with the present study, Ozer et al. [17] reported that the use of combined amalgam-composite restorations has the advantage of reducing gingival microleakage. Also, the use of varnish and adhesive methods reduced microleakage at the junction between amalgam and composite resin [17].

Davari et al. [9] found that the use of amalgam caused less microleakage than RMGI in the floor of the cavity due to the enhancement in the sealing property of amalgam over time and the decline in sealing property of RMGI flood over time and its surface degradation. In contrast to the present study, Tolidis et al. [15] concluded that there is a greater microleakage in amalgam restoration than in composite restoration. However, they attributed this finding to a good initial bond between the composite and the tooth and the samples' short-term storage (7 days) [15].

In contrast to the results of the present study, Cehreli et al. [18] concluded that the microleakage between amalgam and composite is greater than that of amalgam and tooth surface. However, they stated that this study was performed on amalgam that had been repaired for some time and suggested that the leakage would be lower if fresh amalgam was used (similar to our study) [18].

Bulbul [19] stated that the highest bond strength between metals and resin composites occurred when micromechanical methods and physicochemical bonding or their combination were used. The micromechanical method is obtained using sandblasting with aluminum oxide particles, while the chemical bonding occurs through functional monomers of metal primers that are able to bond to the oxidized surface of most metals [19,20]. One of the advantages of primers over micromechanical methods is that this method is easier to use and does not require complex equipment or methods [21]. Alloy primer is a metal sealant used to boost the bond strength of composites and acrylic resins to metals, titanium, and other dental alloys [16].

In line with the present study, Machado et al. found that the use of Universal Primer and Alloy Primer before adhesive systems enhanced the bond strength of composites to metals [22]. Concurring with the present study, Blum et al. [6] found that the simultaneous use of an alloy primer and a type of adhesive (bonding) was better than other methods in reducing the percentage of microleakage at the junction between amalgam and composite restoration. Sarabi et al. [23] also concluded that there was a greater fracture resistance in sandblasted amalgam samples in combined amalgam-composite restorations where 3M bonding was used.

Adhesive resins that contain 4-META have been studied in various articles for about 20 years. These products have provided extraordinary results so far; they are also easy to use and are not technique-sensitive [7]. Although mechanical retention has long been used for bonding composite to amalgam, considering the use of 4-META monomer-based adhesive systems, it is thought that this monomer could react with metals by forming unique bonds with metal oxides or active metal components of amalgam [24].

G-Premio is a universal light-cured bonding agent whose advanced formulation contains 4-META in direct bonding of light-cured composites and compomers to teeth. It is used in the treatment of sensitive teeth, the sealing of cavities in indirect restorations, and the correction of zirconia restorations, metal base, alumina, or composite. Further, it prevents allergic reactions and enjoys a longer shelf life in the oral environment due to the lack of water uptake. Shorter clinical work time, less technical sensitivity, and good bond strength are among the other advantages of this material [25].

The reduction in the microleakage percentage in Group 4 may be due to the simultaneous use of alloy primer and G-Premio, which contain 4-META; that is, 4-META of G- Premio has a synergistic effect on Alloy primer. In this regard, Tsujimoto et al. [26] concluded that shear bond strength, glass ceramic, and zirconia were greater in the metal alloys+ adhesives+ G- Premio bond as compared to Scotch universal bond.

Conclusion

A combined amalgam-composite class II restoration was clinically acceptable regarding microleakage, and the use of a dentin bonding plus alloy primer reduced microleakage. However, an *in vivo* study is recommended to confirm these results.

Authors' Contributions

EZ	https://orcid.org/0000-0003-1489-1388	Conceptualization, Methodology, Formal Analysis, Investigation, Writing - Original Draft, Writing - Review and Editing, Supervision and Project Administration.
FO	https://orcid.org/0000-0002-9265-1470	Data Curation and Writing - Review and Editing.
ZT	https://orcid.org/0000-0001-6088-3456	Data Curation and Writing - Review and Editing.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

Financial Support

This thesis was supported by Research Department of Zanjan University of Medical Sciences (Grant No. A-11-365-10).

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

Acknowledgments

The authors would like to thank Dr. Nima Motamed and the Research Department of Zanjan University of Medical Sciences for assisting us in this research project.

References

[1] Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, et al. State of the art etch-and-rinse adhesives. Dent Mater 2011; 27(1):1-16. https://doi.org/10.1016/j.dental.2010.10.016
[2] Van Meerbeek B, Willems G, Celis J-P, Roos J, Braem M, Lambrechts P, et al. Assessment by nano-indentation of the hardness and elasticity of the resin-dentin bonding area. Dent Res J 1993; 72(10):1434-42. https://doi.org/10.1177/00220345930720101401
[3] Murray PE, Hafez AA, Smith AJ, Cox CF. Bacterial microleakage and pulp inflammation associated with various restorative materials. Dent Mater 2002; 18(6):470-8. https://doi.org/10.1016/s0109-5641(01)00072-0
[4] Demarco F, Ramos O, Mota C, Formolo E, Justino L. Influence of different restorative techniques on microleakage in class II cavities with gingival wall in cementum. Oper Dent 2001; 26(3):253-9.
[5] Kaur G, Singh M, Bal C, Singh U. Comparative evaluation of combined amalgam and composite resin restorations in extensively carious vital posterior teeth: An in vivo study. J Conserv Dent 2011; 14(1):46-51. https://doi.org/10.4103/0972-0707.80742
[6] Blum IR, Hafiana K, Curtis A, Barbour ME, Attin T, Lynch CD, et al. The effect of surface conditioning on the bond strength of resin composite to amalgam. J Dent 2012; 40(1):15-21. https://doi.org/10.1016/j.jdent.2011.10.019
[7] Chang JC, Hurst TL, Hart DA, Estey AW. 4-META use in dentistry: a literature review. J Prosthet Dent 2002; 87(2):216-24. https://doi.org/10.1067/mpr.2002.121584
[8] Özcan M, Koolman C, Aladag A, Dündar M. Effects of different surface conditioning methods on the bond strength of composite resin to amalgam. Oper Dent 2011; 36(3):318-25. https://doi.org/10.2341/10-294-L
[9] Davari A, Daneshkazemi A, Assarzadeh H, Karabi M, Mirhoseini F. Comparing effect of four different restorative techniques with composite on gingival seal located on the dentin. JSSU 2014; 22(3):1196-207.
[10] Turkistani A, Nasir A, Merdad Y, Jamleh A, Alshouibi E, Sadr A, et al. Evaluation of microleakage in class-II bulk-fill composite restorations. J Dent Sci 2020; 15(4):486-92. https://doi.org/10.1016/j.jds.2020.04.007
[11] Bakhsh TA, Sadr A, Shimada Y, Turkistani A, Abuljadayel R, Tagami J. Does lining class-II cavities with flowable composite improve the interfacial adaptation?. J Adhes Sci Technol 2020; 34(4):400-16. https://doi.org/10.1080/01694243.2019.1676589
[12] Turkistani A, Ata A, Alhammad R, Ghurab R, Alahmadi Y, Shuman M, et al. Bulk-fill composite marginal adaptation evaluated by cross-polarization optical coherence tomography. Cogent Engineering 2019; 6(1):1-10. https://doi.org/10.1080/23311916.2019.1643976
[13] Hovav S, Holan G, Lewinstein I, Fuks A. Microleakage of class 2 Superbond-lined composite restorations with and without a cervical amalgam base. Oper Dent 1995; 20(2):63-7.
[14] Belli S, Ünlü N, Özer F. Effect of cavity varnish, amalgam liner or dentin bonding agents on the marginal leakage of amalgam restorations. J Oral Rehabil 2001; 28(5):492-6. https://doi.org/10.1046/j.1365-2842.2001.00676.x
[15] Tolidis K, Boutsiouki C, Gerasimou P. Microleakage in combined amalgam/composite resin restorations in MOD cavities. Bra J Oral Sci 2013; 12(2):100-4.
[16] Ziskind D, Venezia E, Kreisman I, Mass E. Amalgam type, adhesive system, and storage period as influencing factors on microleakage of amalgam restorations. J Prosthet Dent 2003; 90(3):255-60. https://doi.org/10.1016/s0022-3913(03)00421-9
[17] Ozer F, Unlu N, Ozturk B, Sengun A. Amalgam repair: evaluation of bond strength and microleakage. Oper Dent 2002; 27(2):199-203.
[18] Çehreli S, Arhun N, Celik C. Amalgam Repair: Quantitative evaluation of amalgam-resin and resin-tooth interfaces with different surface treatments. Oper Dent 2010; 35(3):337-44. https://doi.org/10.2341/09-135-L

[19] Bulbul M, Kesim B. The effect of primers on shear bond strength of acrylic resins to different types of metals. J Prosthet Dent 2010; 103(5):303-8. https://doi.org/10.1016/S0022-3913(10)60063-7
[20] Di Francescantonio M, Oliveira MTd, Daroz LGD, Henriques GEP, Giannini M. Adhesive bonding of resin cements to cast titanium with adhesive primers. Braz Dent J 2012; 23(3):218-22. https://doi.org/10.1590/S0103-64402012000300006
[21] Fonseca RG, Haneda IG, Adabo GL. Effect of metal primers on bond strength of resin cements to base metals. J Prosthet Dent 2009; 101(4):262-8. https://doi.org/10.1016/S0022-3913(09)60050-0
[22] Machado C, Sanchez E, Alapati S, Seghi R, Johnston W. Shear bond strength of the amalgam-resin composite interface. Oper Dent 2007; 32(4):341-6. https://doi.org/10.2341/06-100
[23] Sarabi N, Moosavi H. The effect of three different amalgam surface treatment methods on composite-amalgam fracture strength. J Mash Dent Sch 2006; 30(1-2):71-8.
[24] Giannini M, Paulillo LAMS, Ambrosano GMB. Effect of surface roughness on amalgam repair using adhesive systems. Braz Dent J 2002; 13(3):179-83. https://doi.org/10.1590/S0103-64402002000300007
[25] Poggio C, Beltrami R, Colombo M, Chiesa M, Scribante A. Influence of dentin pretreatment on bond strength of universal adhesives. Scand J Dent Res 2017; 3(1):30-5. https://doi.org/10.1080/23337931.2017.1305273
[26] Tsujimoto A, Barkmeier WW, Takamizawa T, Wilwerding T, Latta MA, Miyazaki M. Interfacial characteristics and bond durability of universal adhesive to various substrates. Oper Dent 2017; 42(2):E59-E70. https://doi.org/10.2341/15-353-L