

Adhesion of glass ionomer cements to primary dentin using a universal adhesive

Parastoo Iranparvar^{1,A,D,E}, Amir Ghasemi^{2,A,F}, Pouria Iranparvar^{3,B-D}

¹ Department of Pediatric Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

² Department of Restorative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

³ Dental Research Center, Research Institute for Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online)

Dent Med Probl. 2024;61(1):93–98

Address for correspondence

Pouria Iranparvar

E-mail: pouria.ipv@gmail.com

Funding sources

None declared

Conflict of interest

None declared

Acknowledgements

None declared

Received on June 16, 2020

Reviewed on November 25, 2020

Accepted on December 1, 2020

Published online on February 29, 2024

Abstract

Background. Glass ionomers are widely used for restoring carious primary teeth. However, their ability to bond to primary dentin is considered a challenge in pediatric dentistry.

Objectives. The study aimed to evaluate the microshear bond strength (μ SBS) of a resin-modified glass ionomer (RMGI) and a high-viscosity glass ionomer cement (Hv-GIC) to primary dentin using a universal adhesive.

Material and methods. Thirty human primary maxillary canines were cut in half and prepared for the μ SBS test. The specimens ($N = 60$) were assigned to 6 groups. Three groups were defined for RMGI (FUJI II LC) and 3 groups for Hv-GIC (EQUIA Forte): with an immediately curing adhesive (G-Premio); with a delayed curing adhesive; and without an adhesive (control group). After preparing the dentin surfaces, the glass ionomers were bonded using Tygon® tubes with an internal diameter of 0.7 mm. The μ SBS test was performed, and the data was analyzed using two-way analysis of variance (ANOVA) followed by Tukey's post hoc test. Additionally, the failure modes were determined using a stereomicroscope. Six specimens, one for each study group, were prepared for scanning electron microscopy (SEM) analysis to observe the glass ionomer–dentin interface.

Results. The type of glass ionomer did not have a significant effect on the μ SBS ($p = 0.305$). Groups that received universal adhesive application prior to glass ionomer exhibited a significantly higher μ SBS ($p < 0.0001$). However, there was no significant difference between the immediately curing and delayed curing groups ($p = 0.157$). The predominant failure mode was mixed failure.

Conclusions. Higher bond strength of glass ionomers to primary teeth can be achieved by using universal adhesives, which, in addition to the proven benefits of glass ionomers, can improve their clinical success.

Keywords: primary teeth, glass ionomer cements, adhesives

Cite as

Iranparvar P, Ghasemi A, Iranparvar P. Adhesion of glass ionomer cements to primary dentin using a universal adhesive. *Dent Med Probl.* 2024;61(1):93–98. doi:10.17219/dmp/131066

DOI

10.17219/dmp/131066

Copyright

Copyright by Author(s)

This is an article distributed under the terms of the

Creative Commons Attribution 3.0 Unported License (CC BY 3.0)

(<https://creativecommons.org/licenses/by/3.0/>).

Introduction

Glass ionomer cements (GICs) have been widely used in dentistry since their introduction.¹ Some properties such as fluoride release,² preservation of intact dental tissues and chemical adhesion to the tooth structure make them a desirable choice for restoring carious teeth.³ The adhesion mechanism of GICs consists of hydrogen bonds promoted by their free hydrophilic carboxylic groups and a simultaneous ionic exchange at the interface.⁴ Early conventional glass ionomers had some disadvantages, such as unfavorable strength and toughness.⁵ To improve their physical properties, resin-modified glass ionomers (RMGIs) were developed by adding hydrophilic monomers.⁶ In recent years, high-viscosity glass ionomer cements (Hv-GICs) have been developed by modifying the powder/liquid ratio and particle size.⁷ This has resulted in improved fracture toughness and flexural strength, as well as lowered sensitivity to moisture compared to conventional GICs.⁸

Although composite resins usually have better esthetic and mechanical characteristics, their technique sensitivity can be a challenge, especially in less cooperative patients, such as children.⁹ Therefore, in some cases, GIC is the preferred material for restoring carious primary teeth.¹⁰ Additionally, the bond strength of restorative materials may be affected by a lower degree of mineralization and a higher tubular density in primary dentin compared to permanent dentin,^{11,12} making the bond strength of materials to primary dentin a significant concern.

In recent years, universal adhesives (also known as multi-mode adhesives) have been introduced. These are single-bottle, no-mix adhesive systems that can provide adhesion to various substrates.^{13,14} New-generation adhesives can be used in both self-etch and etch-and-rinse modes. However, the self-etch technique simplifies the application process and minimizes errors.¹⁵

Thus, the purpose of this *in vitro* study was to evaluate the bonding properties of an RMGI (FUJI II LC®; GC Corporation, Tokyo, Japan) and a Hv-GIC (EQUIA Forte™; GC Corporation) to the dentin of primary teeth. Since previous studies have shown the effect of bonding agents on improving the bond strength of RMGIs to permanent dentin,^{16,17} we assessed the effect of using a universal adhesive (G-Premio BOND; GC Corporation) on the bond strength of these GICs to primary dentin.

Material and methods

This *in vitro* study was conducted in the Department of Pediatric Dentistry, in collaboration with the Department of Restorative Dentistry at Shahid Beheshti School of Dentistry, Tehran, Iran, after receiving approval from the Committee for Ethics in Research (No. IR.SBMU.DRC.REC.1398.011).

Thirty-six extracted human primary maxillary canines were selected, 6 of which were observed using field emission scanning electron microscopy (FE-SEM). The teeth were examined under a stereomicroscope (SZX9; Olympus, Tokyo, Japan) to confirm the absence of cracks, fractures, caries, restorations, hypoplasia, or anatomical abnormalities.

The teeth had been extracted for orthodontic reasons during the previous 3 months and were kept at room temperature in normal saline, which was replaced weekly. Crowns of the teeth were debrided using a prophylaxis brush on a low-speed handpiece for 30 s and disinfected with 0.5% chloramine T solution. Sixty specimens ($N = 60$) were obtained by sectioning 30 teeth into equal mesial and distal halves using a low-speed cutting machine (IsoMet® Low Speed Precision Cutter; Buehler, Lake Bluff, USA). The roots of all specimens were cut 2 mm below the cemento-enamel junction and discarded. The dentin surfaces were polished for 10 s under running water using 400-, 600-, 800-, and 1000-grit silicon carbide grinding papers (Matador; STARCKE® GmbH & Co. KG, Melle, Germany), respectively.

We randomly assigned 60 specimens to 6 groups, applying EQUIA Forte in 3 groups with different surface treatment methods: with an immediately curing adhesive; with a delayed curing adhesive; and without an adhesive as control. The remaining 3 groups were treated with FUJI II LC using the same methods. Table 1 provides a summary of the dental materials and their composition. In the groups that used an immediately curing bonding agent, a universal adhesive (G-Premio) was applied to the dentin. After 10 s, the adhesive was dried with air spray for 5 s and then light-cured for 10 s using a light-emitting diode (LED) unit (Guilin Woodpecker Medical Instrument Co. Ltd., Guilin, China) with an intensity of 1000 mW/cm². In the delayed curing groups, the bonding agent was applied in the same manner; however, its light activation was delayed until the application of the glass ionomer.

Table 1. Dental materials and their composition

Name	Material type	Composition	Manufacturer
EQUIA Forte	high-viscosity glass ionomer cement	fluoroaluminosilicate glass, water, polyacrylic acid, polybasic carboxylic acid, camphorquinone	GC Corporation, Tokyo, Japan
FUJI II LC	resin-modified glass ionomer	powder: fluoroaluminosilicate glass liquid: water, polyacrylic acid, HEMA, urethane dimethacrylate	GC Corporation, Tokyo, Japan
G-Premio BOND	universal adhesive (8 th generation)	10-MDP, 4-MET, MEPS, BHT, acetone, dimethacrylate resins, initiators, filler, water	GC Corporation, Tokyo, Japan

HEMA – hydroxyethyl methacrylate; 10-MDP – 10-methacryloyloxydecyl dihydrogen phosphate; 4-MET – 4-methacryloyloxyethyl trimellitate; MEPS – methacryloyloxyalkyl thiophosphate methylmethacrylate; BHT – butylated hydroxytoluene.

TYGON® tubes (Saint-Gobain, Paris, France) with an inner diameter of 0.7 mm and a height of 1 mm were prepared for packing the glass ionomers over the dentin samples. The powder and liquid in the FUJI II LC groups were mixed according to the manufacturer's instructions. The mixture was then packed into TYGON tubes placed over the dentin samples and light-cured for 20 s. In the EQUIA Forte groups, pre-loaded capsules were mixed for 10 s and packed into TYGON tubes placed over the samples. The samples were left to self-cure for 2 min and then covered with an EQUIA coat, a special coating that was light-cured for 20 s according to the manufacturer's instructions. In the delayed curing groups, light activation of the bonding agent and glass ionomer occurred simultaneously at this stage. After 24 h of immersion in distilled water and incubation at 37°C, the TYGON tubes were carefully removed using a scalpel. The specimens were then subjected to the microshear bond strength (μ SBS) test.

Bond strength was measured using a Microtensile Tester (Bisco Inc., Schaumburg, USA) that was transformed into a microshear tester by attaching metallic cylinders with a diameter of 1 mm to one of its working plates. Samples were fixed onto the other working plate of the tester machine using a cyanoacrylate adhesive. An orthodontic wire (0.2 mm in diameter) was formed into a loop to connect the metallic cylinder to the base of the glass ionomer cylinder. The bonded interface, the wire loop and the center of the metallic cylinder were aligned as straight as possible. Microshear forces were applied at a crosshead speed of 0.5 mm/min until debonding occurred, and the μ SBS was recorded.

Failure modes were evaluated using the stereomicroscope at $\times 20$ magnification. The results were recorded as adhesive (fracture at the glass ionomer–dentin interface), cohesive (fracture within the glass ionomer or bonding agent) or mixed (a combination of both failures).

The remaining 6 primary canines, one for each study group, were selected for SEM observations. We cut the upper third of the crowns to expose a flat dentin surface. We prepared the dentin surfaces in the same way as the previous specimens and applied a bulk of glass ionomer. Then, we longitudinally sectioned the specimens using an IsoMet Low-Speed Precision Cutter to reach the glass

ionomer–dentin interface. The specimens were polished using silicon carbide papers with grits of 400, 600, 800, 1000, and 2000, followed by cleaning with 37% phosphoric acid for 5 s and thorough rinsing for 30 s. All specimens were dehydrated using a desiccator containing silica gel for 24 h. After sputter coating, the glass ionomer–dentin interfaces were observed using a FE-SEM (S-4160; Hitachi, Tokyo, Japan) at $\times 500$ magnification.

Statistical analysis

Data was analyzed using the IBM SPSS Statistics for Windows software, v. 25.0 (IBM Corp., Armonk, USA). A two-way analysis of variance (ANOVA), followed by Tukey's post hoc test, was used to determine the difference in bond strength between the groups. Failure mode analysis was conducted using the χ^2 tests. The level of significance set for the study was ≤ 0.05 .

Results

Descriptive statistics of μ SBS for the 6 groups are shown in Table 2. According to the results of the two-way ANOVA test, the glass ionomer type did not have a significant effect on μ SBS ($p = 0.305$). However, the effect of surface treatment was significant ($p < 0.0001$). In addition, the interaction effect between surface treatment and the type of glass ionomer was not significant ($p = 0.558$). Post hoc Tukey's Honest Significant Difference (HSD) test was performed to compare 3 surface treatment methods (i.e., an immediately curing adhesive, a delayed curing adhesive, and without an adhesive). It was shown that the groups with an adhesive had significantly higher μ SBS values than the control group ($p < 0.0001$). However, there was no significant difference between the immediately curing and delayed curing adhesive groups ($p = 0.157$).

The distribution of failure modes among the 6 study groups did not show any significant difference ($p = 0.974$). The most frequently observed failure mode was mixed failure, while the cohesive mode had the lowest proportion. Table 2 shows the distribution of failure modes within the groups.

Table 2. Descriptive statistics of microshear bond strength (μ SBS) and failure mode for the 6 groups

Group	μ SBS [MPa] <i>M</i> $\pm$ <i>SD</i>	Failure mode [%]		
		adhesive	cohesive	mixed
FUJI II LC without an adhesive	6.72 $\pm$ 1.28	40	10	50
FUJI II LC with an immediately curing adhesive	10.72 $\pm$ 1.61	40	20	40
FUJI II LC with a delayed curing adhesive	9.58 $\pm$ 0.96	30	20	50
EQUIA Forte without an adhesive	6.3 $\pm$ 1.1	50	0	50
EQUIA Forte with an immediately curing adhesive	10.02 $\pm$ 1.24	40	10	50
EQUIA Forte with a delayed curing adhesive	9.71 $\pm$ 1.06	40	20	40

M – mean; *SD* – standard deviation.

The SEM images of the glass ionomer–dentin interfaces are presented in Fig. 1. All groups showed gap formation. In the groups with an immediately curing adhesive, the fracture occurred within the glass ionomer, and the glass ionomer–adhesive interaction was maintained in most parts. However, in the groups with a delayed curing adhesive, the layer of bonding agent was imperceptible.

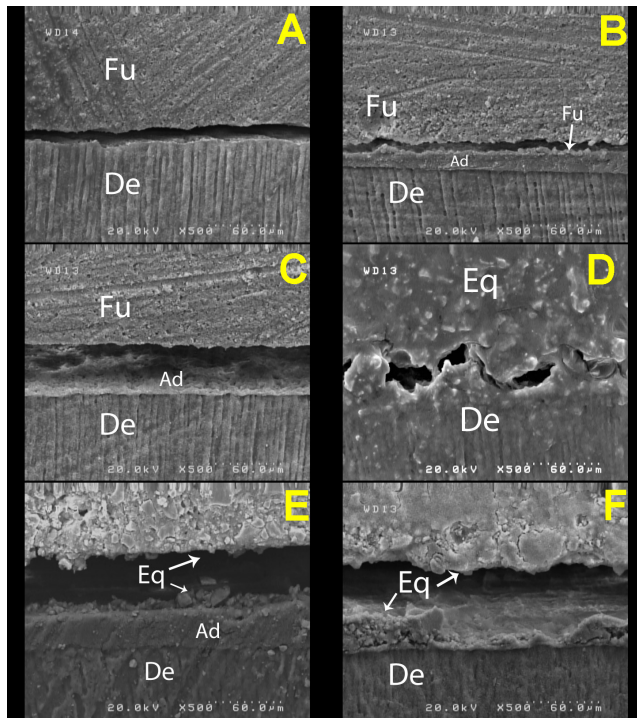


Fig. 1. Scanning electron microscopy (SEM) images (x500 magnification) A. FUJI II LC without an adhesive; B. FUJI II LC with an immediately curing adhesive; C. FUJI II LC with a delayed curing adhesive; D. EQUIA Forte without an adhesive; E. EQUIA Forte with an immediately curing adhesive; F. EQUIA Forte with a delayed curing adhesive. Fu – FUJI II LC; De – dentin; Ad – adhesive; Eq – EQUIA Forte.

Discussion

The bond strength of restorative dental materials plays a crucial role in the treatment success by preventing marginal gapping and microleakage.^{4,18} We aimed to assess the bonding properties of RMGI (FUJI II LC) and Hv-GIC (EQUIA Forte) to primary dentin, considering the limited evidence on the bond strength of GICs to primary teeth and the improved physical characteristics of modified glass ionomers. FUJI II LC is a commonly used material in pediatric dentistry, while EQUIA Forte is a new-generation glass ionomer. Previous studies have not evaluated their bonding properties in primary teeth.

Both macro- and micro-tests can be used to measure bond strength, either tensile or shear. However, they differ in the cross-sectional area being bonded. This study used a micro-test to minimize false failures and errors that may occur due to the larger size of samples in macro-tests.¹⁹ The μ SBS measurement method is useful for materials

like glass ionomers, because their properties make them susceptible to the specimen preparation and testing conditions of micro-tensile bond strength tests.²⁰ In our laboratory, we converted the design of a micro-tensile testing machine into a microshear tester, as described in the methods section. Shear force was applied using a wire loop, as described in previous studies.^{21–23} The wire loop design allows for stress to be concentrated closer to the interface area compared to the knife-edge design.¹⁹

When evaluating the effect of bonding agent application prior to glass ionomers, we observed a significantly improved bond strength in both types of glass ionomers. Since RMGIs contain resin components, the benefits of both a chemical bond through ionic exchange and a micromechanical bond can be achieved by using a bonding agent.²⁴ This observation has been reported in previous studies that used various types of bonding agents. Nakanuma et al.¹⁶ reported a significant improvement in the tensile bond strength of FUJI II LC to permanent dentin when using a dentin bonding agent in addition to different primers. Similarly, Poggio et al.²⁵ found that the bond strength of FUJI II LC to bovine dentin significantly increased when using a self-etch adhesive prior to the glass ionomer, which is consistent with our results. Besnault et al.²⁶ observed a significantly higher shear bond strength of FUJI II LC to permanent dentin using 7 different self-etch adhesives, which is consistent with our study. The bond strength of FUJI II LC increased after the application of a universal adhesive in our study, which may be due to several factors, including the presence of unsaturated carbon–carbon bonds in the FUJI II LC and G-Premio bonds, which can form covalent bonds during polymerization. Additionally, the hydrophilic nature of both RMGI and a universal adhesive can improve the compatibility between the 2 materials.²⁶

The evidence regarding the effect of bonding agents on the bond strength of EQUIA Forte is limited. However, it is presumed that a chemical reaction occurs between the universal adhesive and the calcium ions of EQUIA Forte via dihydrogen phosphate groups of its 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP),²⁷ which can explain the bond strength improvement observed in our study.

According to our results, the bond strength measurements were not significantly affected by the type of glass ionomer. This is consistent with the results of a previous study by Latta et al.,²⁸ which compared the shear bond strength of FUJI II LC and EQUIA Forte on permanent teeth and found no significant differences between them. Yao et al.²⁹ showed a significantly higher tensile bond strength of FUJI II LC to both flat and cavity-formed permanent dentin when compared to EQUIA Forte. This discrepancy might be justified by the fact that no dentin pre-treatments were applied in the EQUIA Forte group in their study, which could have reduced micromechanical interlocking formation due to the interference of the

smear layer. The polished surfaces in our specimens minimize the smear layer thickness and provide better bonding opportunities for self-adhesive materials. Additionally, the abovementioned study did not apply an EQUIA Forte coat. This resin-based coating agent fills the porosities and cracks and prevents the early setting of GICs in a moist environment.²⁹

The most frequently observed failure mode in both GICs was mixed failure, which is consistent with a study by Abdelmegid et al.³⁰ In SEM observations, the interactions between the glass ionomer and adhesive were maintained in all specimens. However, gap formation was evident after desiccation and resin tags were not observed. In a previous study conducted by Pereira et al.,¹⁷ resin tags were formed in FUJI II LC. This difference could be attributed to the surface treatment methods and the type of adhesive system used.

A meta-analysis has shown that GICs have clinical performance comparable to composite resins in various aspects, including marginal adaptation and secondary caries, for Class II restoration of primary teeth.⁹ Therefore, GICs can be considered for permanent restoration of primary teeth, especially in high-caries patients.³ A universal adhesive can increase the bond strength of GICs and contribute to their improved clinical performance.

One of the limitations of the present study was its in vitro design, which overlooks the impact of the oral environment on bond durability. Since the measurements were performed on healthy dentin, further studies on caries-affected dentin and long-term evaluations of bond strength are recommended.

Conclusions

The bond strength of the examined glass ionomers was significantly improved by applying a universal adhesive to primary dentin. Our results suggest that this improvement can increase the clinical success of glass ionomer restorations in primary teeth, given the desirable properties of GICs.

Ethics approval and consent to participate

The study was approved by the Committee for Ethics in Research (approval No. IR.SBMU.DRC.REC.1398.011).

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

ORCID iDs

Parastoo Iranparvar  <https://orcid.org/0000-0001-7071-2124>

Amir Ghasemi  <https://orcid.org/0000-0002-2748-1778>

Pouria Iranparvar  <https://orcid.org/0000-0002-7378-4622>

References

1. Sidhu SK, Nicholson JW. A review of glass-ionomer cements for clinical dentistry. *J Funct Biomater*. 2016;7(3):16. doi:10.3390/jfb7030016
2. Mukai M, Ikeda M, Yanagihara T, et al. Fluoride uptake in human dentine from glass-ionomer cement in vivo. *Arch Oral Biol*. 1993;38(12):1093–1098. doi:10.1016/0003-9969(93)90171-h
3. Daou MH, Tavernier B, Meyer JM. Two-year clinical evaluation of three restorative materials in primary molars. *J Clin Pediatr Dent*. 2009;34(1):53–58. doi:10.17796/jcpd.34.1.h4p6141065388h0h
4. Ngo HC, Mount G, Mc Intyre J, Tuisuva J, Von Doussa RJ. Chemical exchange between glass-ionomer restorations and residual carious dentine in permanent molars: An in vivo study. *J Dent*. 2006;34(8):608–613. doi:10.1016/j.jdent.2005.12.012
5. Yli-Urpo H, Lassila LVJ, Närhi T, Vallittu PK. Compressive strength and surface characterization of glass ionomer cements modified by particles of bioactive glass. *Dent Mater*. 2005;21(3):201–209. doi:10.1016/j.dental.2004.03.006
6. Berzins DW, Abey S, Costache MC, Wilkie CA, Roberts HW. Resin-modified glass-ionomer setting reaction competition. *J Dent Res*. 2010;89(1):82–86. doi:10.1177/0022034509355919
7. Balkaya H, Arslan S, Pala K. A randomized, prospective clinical study evaluating effectiveness of a bulk-fill composite resin, a conventional composite resin and a reinforced glass ionomer in Class II cavities: One-year results. *J Appl Oral Sci*. 2019;27:e20180678. doi:10.1590/1678-7757-2018-0678
8. Çelik EU, Tunac AT, Yilmaz F. A randomized, controlled, split-mouth trial evaluating the clinical performance of high-viscosity glass-ionomer restorations in noncarious cervical lesions: Two-year results. *J Adhes Dent*. 2018;20(4):299–305. doi:10.3290/j.jad.a40985
9. Dias AGA, Magno MB, Delbem ACB, Cunha RF, Maia LC, Pessan JP. Clinical performance of glass ionomer cement and composite resin in Class II restorations in primary teeth: A systematic review and meta-analysis. *J Dent*. 2018;73:1–13. doi:10.1016/j.jdent.2018.04.004
10. Cho SY, Cheng AC. A review of glass ionomer restorations in the primary dentition. *J Can Dent Assoc*. 1999;65(9):491–495. PMID:10560209.
11. Angker L, Swain MV, Kilpatrick N. Micro-mechanical characterisation of the properties of primary tooth dentine. *J Dent*. 2003;31(4):261–267. doi:10.1016/s0300-5712(03)00045-9
12. Pires CW, Soldera EB, Bonzanini LIL, et al. Is adhesive bond strength similar in primary and permanent teeth? A systematic review and meta-analysis. *J Adhes Dent*. 2018;20(2):87–97. doi:10.3290/j.jad.a40296
13. Alex G. Universal adhesives: The next evolution in adhesive dentistry? *Compend Contin Educ Dent*. 2015;36(1):15–26. PMID:25822403.
14. Kharouf N, Rapp G, Mancino D, Hemmerlé J, Haikel Y, Reitzer F. Effect of etching the coronal dentin with the rubbing technique on the microtensile bond strength of a universal adhesive system. *Dent Med Probl*. 2019;56(4):343–348. doi:10.17219/dmp/111697
15. da Silva Sutil BG, Susin AH. Dentin pretreatment and adhesive temperature as affecting factors on bond strength of a universal adhesive system. *J Appl Oral Sci*. 2017;25(5):533–540. doi:10.1590/1678-7757-2016-0500
16. Nakanuma K, Hayakawa T, Tomita T, Yamazaki M. Effect of the application of dentin primers and a dentin bonding agent on the adhesion between the resin-modified glass-ionomer cement and dentin. *Dent Mater*. 1998;14(4):281–286. doi:10.1016/s0109-5641(98)00040-2
17. Pereira PN, Yamada T, Inokoshi S, Burrow MF, Sano H, Tagami J. Adhesion of resin-modified glass ionomer cements using resin bonding systems. *J Dent*. 1998;26(5–6):479–485. doi:10.1016/s0300-5712(97)00059-6
18. Fortin D, Swift EJ Jr, Denehy GE, Reinhardt JW. Bond strength and microleakage of current dentin adhesives. *Dent Mater*. 1994;10(4):253–258. doi:10.1016/0109-5641(94)90070-1

19. Van Meerbeek B, Peumans M, Poitevin A, et al. Relationship between bond-strength tests and clinical outcomes. *Dent Mater.* 2010;26(2):e100–e121. doi:10.1016/j.dental.2009.11.148
20. Armstrong S, Geraldini S, Maia R, Araújo Raposo LH, Soares CJ, Yamagawa J. Adhesion to tooth structure: A critical review of “micro” bond strength test methods. *Dent Mater.* 2010;26(2):e50–e62. doi:10.1016/j.dental.2009.11.155
21. Shimada Y, Yamaguchi S, Tagami J. Micro-shear bond strength of dual-cured resin cement to glass ceramics. *Dent Mater.* 2002;18(5):380–388. doi:10.1016/s0109-5641(01)00054-9
22. Harnirattisai C, Roengrungreang P, Rangsisiripaiboon U, Senawongse P. Shear and micro-shear bond strengths of four self-etching adhesives measured immediately and 24 hours after application. *Dent Mater J.* 2012;31(5):779–787. doi:10.4012/dmj.2012-013
23. Emamieh S, Elahi M, Ghasemi A. Effect of two universal adhesives on microshear bond strength of resin cement to zirconia. *Dent Med Probl.* 2019;56(3):245–249. doi:10.17219/dmp/109349
24. Welch D, Seesengood B, Hopp C. Surface treatments that demonstrate a significant positive effect on the shear bond strength of repaired resin-modified glass ionomer. *Oper Dent.* 2015;40(4):403–409. doi:10.2341/13-314-L
25. Poggio C, Beltrami R, Scribante A, Colombo M, Lombardini M. Effects of dentin surface treatments on shear bond strength of glass-ionomer cements. *Ann Stomatol (Roma).* 2014;5(1):15–22. doi:10.11138/ads/2014.5.1.015
26. Besnault C, Attal JP, Ruse D, Degrange M. Self-etching adhesives improve the shear bond strength of a resin-modified glass-ionomer cement to dentin. *J Adhes Dent.* 2004;6(1):55–59. PMID:15119588.
27. Francois P, Vennat E, Le Goff S, Ruscassier N, Attal JP, Dursun E. Shear bond strength and interface analysis between a resin composite and a recent high-viscous glass ionomer cement bonded with various adhesive systems. *Clin Oral Investig.* 2019;23(6):2599–2608. doi:10.1007/s00784-018-2678-5
28. Latta MA, Tsujimoto A, Takamizawa T, Barkmeier WW. Enamel and dentin bond durability of self-adhesive restorative materials. *J Adhes Dent.* 2020;22(1):99–105. doi:10.3290/j.jad.a43996
29. Yao C, Ahmed MH, Okazaki Y, Van Landuyt KL, Huang C, Van Meerbeek B. Bonding efficacy of a new self-adhesive restorative onto flat dentin vs class-I cavity-bottom dentin. *J Adhes Dent.* 2020;22(1):65–77. doi:10.3290/j.jad.a43999
30. Abdelmegid F, Salama F, Albogami N, Albabtain M, Alqahtani A. Shear bond strength of different dentin substitute restorative materials to dentin of primary teeth. *Dent Mater J.* 2016;35(5):782–787. doi:10.4012/dmj.2016-003