Bond Integrity of Resin-modified Glass Ionomer to Dentin Conditioned Using Photodynamic Therapy and Low-level Laser Therapy: An In Vitro Study

Mohammed S Bin-Shuwaish¹, Abdullah S AlJamhan²

ABSTRACT

Aim: The aim of the study was to assess the conditioning efficacy of photodynamic therapy (PDT) and Er,Cr:YSGG laser (ECYL) to dentin compared with conventional regime bonded to resin-modified glass ionomer (RMGIC).

Materials and methods: Forty mandibular teeth were cleaned, disinfected, and mounted vertically within the segments of polyvinyl pipes up to cementoenamel junction. The occlusal surfaces were flattened, and samples were divided into four groups according to conditioning protocols. Samples in groups I and II underwent PDT, samples in group III were conditioned with low-level laser therapy (LLLT) using Er,Cr:YSGG laser (ECYL), and samples in group IV were conditioned using polyacrylic acid (PAA). Fuji II LC was applied incrementally and light cured for 20 seconds. All samples were placed in universal testing machine for shear bond strength (SBS) testing. The fracture surface was analyzed using stereomicroscope at 50× magnification to determine mode of failure. Among different investigational groups Tukey test was used as post hoc along with analysis of variance (ANOVA). Significance level was established at p < 0.05.

Results: Maximum SBS values were observed in group IV dentin conditioned with PAA (19.55 ± 1.84 MPa), whereas minimum SBS values were shown by group I (methylene blue photosensitizer, MBP) activated by PDT (13.52 ± 1.22 MPa). In group III, dentin conditioned with ECYL (18.22 ± 2.07 MPa) and group IV (19.55 ± 1.84 MPa) surface treated with PAA exhibited comparable SBS values (p > 0.05). Fracture analysis revealed that in PDT group adhesive failure type was in majority. However, adixed failure type was commonly presented in groups III and IV.

Conclusion: PDT of dentin using photosensitizers MBP and CP deteriorates bond values when bonded to RMGIC. The use of LLLT to condition dentin has the potential to improve SBS.

Clinical significance: Dentin conditioning with LLLT using ECYL may improve, is of utmost importance for better treatment outcome, predictable prognosis, and improved bond integrity to RMGIC.

Keywords: Dentin conditioning, Low-level laser therapy, Photodynamic therapy, Photosensitizers, Resin-modified glass ionomer cement, Shear bond strength.

The Journal of Contemporary Dental Practice (2020): 10.5005/jp-journals-10024-2948

INTRODUCTION

Bonded restorations have gained increasing popularity in modern dentistry. The reliable adhesive nature of existing restorative materials to tooth structure has resulted in conservation and minimal removal of teeth, which indirectly has improved treatment outcomes leading to a better prognosis. It has always been challenging for clinicians to find a restorative material having physical/chemical characteristics similar to those of a natural tooth, as well as being biocompatible with enamel and dentin with minimal degradation in oral environment. Initially, glass ionomer cements (GICs) were widely used, since, they showed better physiochemical bonding to dentin and better bond integrity compared to adhesive resins. However, GIC was restricted due to their clinical shortcomings, such as poor setting time, moisture sensitivity, and rough surface after setting, thus hampering mechanical resistance.

To overcome the limitations of GICs, resin-modified glass ionomer cements (RMGICs) were introduced with proper handling characteristics and improved properties compared with those of conventional GICs. However, available evidence indicates that RMGIC requires conditioning of tooth structure prior to restoration to improve bond integrity, whereas other lab-based studies have suggested that surface treatment of dentinal structure is not critical to improve bond values. Different conditioning regimes are used to remove smear layer. Among them, polyacrylic acid (PAA) is considered to be the mainstay. PAA is a polyelectrolyte exhibiting high water absorbance, robust mechanical properties, well-known biocompatibility, and protein resistance and thus has been widely applied to condition dentin and improve bond values.

Recently, different treatment modalities have been proposed to condition dentin. These include photodynamic therapy (PDT) and low-level laser therapy (LLLT) using Er,Cr:YSGG laser (ECYL). PDT activates photosensitizers (PS) resulting in reactive oxygen species (ROS) accountable for smear layer removal and bacterial lysis. PDT with different PS has recently been used by Alrahlah et al.,

[1,2]Department of Restorative Dental Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia

Corresponding Author: Abdullah S AlJamhan, Department of Restorative Dental Sciences, King Saud University, Riyadh, Kingdom of Saudi Arabia, Phone: +966 1 8064701, e-mail: a.aljamhan@ksu.edu.sa

How to cite this article: Bin-Shuwaish MS, AlJamhan AS. Bond Integrity of Resin-modified Glass Ionomer to Dentin Conditioned Using Photodynamic Therapy and Low-level Laser Therapy: An In Vitro Study. J Contemp Dent Pract 2020;21(11):1229–1232.

Source of support: Nil

Conflict of interest: None

© Jaypee Brothers Medical Publishers. 2020 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.
and Al Deeb et al.,13 on carious dentin structure with favorable outcomes. Similarly, Strazi-Sahyon et al.,14 and Vohra et al.,11 used this technique in radicular dentin to improve bond strength of fiber posts. Another alternative in the form of ECYL has gained attention. ECYL works at a wavelength of 2780 nm and removes the smear layer and is readily absorbed by the biological tissues.15 ECYL has been used to condition different dental materials and dentinal structures demonstrating favourable outcomes.11,15–19

To the best of our knowledge from the available indexed literature, reports on the use of ECYL to condition dentin prior to RMGICs are scarce with heterogeneous results. Moreover, PDT for dentin conditioning with Curcumin and methylene blue photosensitizers (MBP) is unprecedented. It is hypothesized that conventional conditioning regimes using PAA will result in better SBS compared to ECYL and PDT. Therefore, the purpose of the current study was to assess the conditioning efficacy of PDT and ECYL to dentin compared with conventional regime bonded to RMGIC.

Materials and Methods

The study was approved by the ethics committee of King Saud University and followed check list of reporting invitro studies (CRIS) guidelines. Forty mandibular non traumatized, unrestored molar, free from carious lesion and cracks, were collected in a period of six months were extracted for periodontal reasons. Inorganic and organic remnants from root part of samples were cleaned by means of a periodontal scaler and curette (Perio soft-scaler, Kerr Dental, Orange, CA, USA) and disinfected in 10% formalin for one week.

All samples were mounted vertically within segments of polyvinyl pipes (3 mm radius) up to cementoenamel junction using self-cure acrylic (Technovit 4004, Heraeus Kulzer, Wehrheim, Germany). The occlusal surfaces of all mandibular samples were made uniform and flattened with water-cooled diamond saw (Refine saw low, Refine Tec, Yokohama, Japan) and finished with 600-grit silicon carbide paper. Based on surface conditioning protocols all samples were divided into four groups (n = 10).

Dentin Conditioning Protocols

Group I: MBP (Sigma Aldrich, Merck, Germany) was used at 100 mg/L to treat dentinal surfaces. Agitation on the surface was created using ultrasonic scaler. MBP was activated using monochromatic diode laser (ODI Technology Guangdong, China) at 808 nm wavelength at 1.5 watts power in a continuous mode. The 400 nm tip of diode laser was positioned parallel to the dentinal surface for a duration of 60 seconds. Following PDT, the dentinal surface was washed for 5 seconds with distilled water.

Group II: 500 mg/L curcumin photosensitizer (CP) was used for conditioning of dentin. Curcumin was applied on dentin and activated using PDT under blue phase light-emitting diode (LED) [Foshan Anmon (ANDER) Medical Equipment Co., Ltd, Foshan, China], at a wavelength range from 430 to 485 nm. From the dentinal surface, the tip was placed vertically with output intensity of 900 mW/cm² to 1500 mW/cm². Following PDT, the dentinal surface was washed for 5 seconds with distilled water.

Group III: LLLT using ECYL was used at 30 Hz frequency and 0.5 W of power in a non-contact circular motion over the dentin surface. The distance of tip MZ 8 was kept 2 mm from the dentin surface. The irradiation time was 60 seconds for each sample. The water-air ratio was maintained constant at a ratio of 55–65%.

Group IV (control): Samples in this group were conditioned using PAA (Shandong Look Chemical Co., Ltd, Shandong, China) for 30 seconds, washed for 10 seconds with water aerosols, and air dried.

After conditioning of dentinal surface, Fuji II LC (GC Corp, Japan) was mixed according to the manufacturer recommendations, then applied incrementally (2 mm in thickness), and light cured for 20 seconds with 1200 mW/cm² radiant exposure (Bluephase G2, Ivoclar, Vivadent, Schaan, Liechtenstein). All samples were placed in distilled water for 48 hours at 24°C prior to shear bond strength (SBS) testing.

Testing of SBS and Fracture Analysis (FA)

All samples were placed in a universal testing machine (Model 3343, Instron Corporation, Norwood, MA, USA) directed at the mandibular jaw, with the bonded cylinder base parallel to the direction of force. Force was applied at a speed of 1 mm/minute until failure of RMGIC and dentin occurred. The force required to debond surface was measured in Megapascals (MPa). The fracture surface was analyzed by stereomicroscope (Stereomicroscope SR, Zeiss, Oberkochen, Germany) at 50x magnification to determine modes of failure classified into cohesive, admixed, and adhesive. All the experimentation steps were done by a single investigator.

Statistical Evaluation

Statistical program for social science (SPSS version 19, Inc., Chicago, US) was used to determine analysis for mode of failure and SBS. Among the different investigational groups, post hoc Tukey test was used along with analysis of variance (ANOVA). Significance level was established at p < 0.05.

Results

Assessment of normality of data was established by Levine’s test. As displayed in Table 1, maximum SBS value was observed in group IV of dentin surface conditioned with PAA (19.55 ± 1.84 MPa), whereas the minimum SBS values were shown in group I MBP activated by PDT (13.52 ± 1.22 MPa).

In group III, dentin conditioned with ECYL (18.22 ± 2.07 MPa) and group IV (19.55 ± 1.84 MPa) surface treated with PAA exhibited comparable SBS values (p > 0.05). Moreover, SBS values in group III and IV were found to be significantly higher than group I and II of surfaces treated with curcumin, activated by PDT (p < 0.05) (Fig. 1).

Table 1: Using ANOVA and Tukey multiple comparisons tests for means and SD for bond strength values among different study groups

| Material type          | Type of conditioning | Mean ± SD (MPa) | p value* |
|------------------------|----------------------|----------------|---------|
| Fuji II LC RMGIC       | Group I: Methylene blue photosensitizer (MBP) | 13.52 ± 1.22A | <0.05   |
|                        | Group II: Curcumin photosensitizer (CP)       | 14.88 ± 1.01A |         |
|                        | Group III: Er3¿Cr3¿:YSGG laser (ECYL)         | 18.22 ± 2.07B |         |
|                        | Group IV: Surface conditioner polyacrylic acid (PAA) (control) | 19.55 ± 1.84B |         |

A,BIndicate a statistically significant difference (Tukey multiple comparison test) (p < 0.05)

*Showing significant difference among study groups (ANOVA)
Fracture analysis revealed adhesive failure type in majority. However, the admixed failure type was commonly presented in group III and IV (Table 2 and Fig. 2).

**DISCUSSION**

This study was constructed on the supposition that conventional conditioning regimes using PAA will exhibit better SBS compared with those involving ECYL and PDT. Interestingly, the hypothesis was partly accepted, since conditioning by ECYL exhibited comparable results with those for PAA, whereas surface treatment of dentin with curcumin photosensitizer (CP) and MBP prior to restoration with RMGIC revealed significantly lower SBS.

The resilience of the restoration is dependent on the quality of adhesive, which in the present study, was assessed by means of a universal testing machine in the present study. The testing method provides quantitative comparative analysis among different investigational groups, is cost effective, simple to use, and standardized. Moreover, the test is recommended for RMGIC, since it provides efficient screening and depth profiling of the material and has an added advantage of testing the bond strength to various substrates.

Dentin bonding has always been a complex issue due to its histological characteristic, and variation in composition, and moisture physiognomies. Therefore, to obtain a predictable bonding between RMGIC and dentin, conditioning is advisable as it improves wettability, permeability, and SBS. In the present study, PDT with MBP and curcumin was used to condition dentin prior to the application of RMGIC and was found to have lowest bond scores value (13.52 ± 1.22 MPa) (14.88 ± 1.01 MPa). There are multiple explanations for these outcomes. MPB is cationic in nature, with affinity for anionic molecule like phosphorus in hydroxyapatite of dentin. This affinity would have led to an imbalance in the calcium/phosphorus ratio resulting in precipitation between dentin and RMGIC and compromising bond integrity. Moreover, the hydrophilic nature of MBP and curcumin at this concentration may have allowed for water sorption causing bond values to deteriorate. Similarly, CP when activated results in significant changes in dentin surface, as it does not lead to formation of singlet oxygen (O2); but rather, forms hydrogen peroxide (H2O2) which on breakdown results in H2O on the dentin surface, hence compromising bond values.

The conditioning of dentin by LLLT with ECYL demonstrated bond strength values of (18.22 ± 2.07 MPa) comparable with those of control PAA (19.55 ± 1.84 MPa). ECYL when used at low frequency and power results in thermomechanical ablation of the dentinal surface. Moreover, it causes water evaporation from the organic component of dentin, improves the concentration of calcium and phosphate ions, and forms an intermedullary layer between dentin and RMGIC promoting the exchange of ions which indirectly improves bond values. Furthermore, LLLT when used to condition dentin results in protrusion and opening of dentinal tubules which makes the structure more receptive to bonding. Our findings were in agreement with those reported by Garbui et al. and Ekworapoj et al. However, work by Jordehi et al. and Sakr stated that ECYL has an unfavorable effect on dentin and SBS. This heterogeneity in studies can be explained by the use of different laser parameters and prototypes, types of human/bovine dentin, duration and distance of laser used, and kind of RMGIC. PAA along with ECYL also enhanced bond strength of RMGIC. A probable explanation for this is enhanced micro-retention with better adaptation and infiltration of RMGIC in resin tags.

Fracture analysis revealed adhesive failure type in PDT groups. In group III treated with laser and in PAA group IV admixed failure was observed. A probable explanation for adhesive failure is porosity within RMGIC resulting in fracture and stress within the cement itself. Moreover, admixed failure type in laser-treated group can be the cause of thermo ablation of dentin effecting the physical properties, i.e., hardness, flexural strength, and tensile strength.
The conclusions of the present study are valid for the type of conditioning regimes, laser parameters, photosensitizers, and RMGIC. The use of different photosensitizers as dentin conditioners with different concentrations and their effects on the mechanical properties of dentin require further investigation. Moreover, microleakage assessment, Raman spectroscopy, and Scanning electron microscopy (SEM) along with durability studies require additional examination. Based on the results of the current study, the authors recommend conditioning of RMGIC with LLLT and PDT. However, more in vitro and in vivo studies are recommended to extrapolate the findings and conclusions of the present study.

**Conclusion**

Conditioning of dentin using PAA prior to the application of RMGIC improves SBS. PDT of dentin using photosensitizers MBP and CP causes bond values to deteriorate when bonded to RMGIC. The use of LLLT to condition dentin has the potential to improve SBS.

**References**

1. Yip HK, Tay FR, Ngo HC, et al. Bonding of contemporary glass ionomer cements to dentin. Dent Mater 2001;17(5):456–470. DOI: 10.1016/S0109-5641(01)00007-0.
2. Liu Y, Tjaderhane L, Breschi L, et al. Limitations in bonding to dentin and experimental strategies to prevent bond degradation. J Dent Res 2011;90(8):953–968. DOI: 10.1177/0022034510391799.
3. Di Nicolò R, Shinomura E, Myakie SI, et al. Bond strength of resin modified glass ionomer cement to primary dentin after cutting with different bur types and dentin conditioning. J Appl Oral Sci 2007;15(5):459–464. DOI: 10.1590/S1678-77952007000500016.
4. Banomyong D, Palamara A, Duncan A, et al. Effect of dentin conditioning on dentin permeability and micro-shear bond strength. Eur J Oral Sci 2007;115(6):502–509. DOI: 10.1111/j.1600-0722.2007.00483.x.
5. Poggio C, Belltrami R, Scibante A, et al. Effects of dentin surface treatments on shear bond strength of glass-ionomer cements. Ann Stomatol (Roma) 2014;5(1):15–22. http://www.ncbi.nlm.nih.gov/pubmed/24753797. Accessed June 9, 2019.
6. Imbery T, Nambodiri A, Duncan A, et al. Evaluating dentin surface treatments for resin-modified glass ionomer restorative materials. Oper Dent 2012;38(4):429–438. DOI: 10.2341/12-162-I.
7. Jordehi AV, Ghasemi A, Zadeh MM, et al. Evaluation of Microtensile bond strength of glass ionomer cements to dentin after conditioning with the Er:Cr:YSGG laser. Photomed Laser Surg 2007;25(5):402–406. DOI: 10.1089/pho.2006.2074.
8. Rai N, Naik R, Gupta R, et al. Evaluating the effect of different conditioning agents on the shear bond strength of resin-modified glass ionomers. Contemp Clin Dent 2017;8(4):604. DOI: 10.4103/ccd.ccd_631_17.
9. Saura S, Watson T, Mocardo AP, et al. The effect of dentine pre-treatment using bioglass and/or polyacrylic acid on the interfacial characteristics of resin-modified glass ionomer cements. J Dent 2016;73:32–39. DOI: 10.1016/j.jdent.2018.03.014.
10. Garbui BU, de Azevedo CS, Zezelli DM, et al. Er:Cr:YSGG laser dentine conditioning improves adhesion of a glass ionomer cement. Photomed Laser Surg 2013;31(9):453–460. DOI: 10.1089/pho.2013.3546.
11. Vohra F, Buchhari IA, Sheikh SA, et al. Photodynamic therapy and activations of irradiation (using different laser prototypes) on push out bond strength of fiber posts. Photodiagnostics Photodyn Ther 2020;30:101716. DOI: 10.1016/j.pdpdt.2020.101716.
12. Alrahlah A, Niaz MO, Abrar E, et al. Treatment of caries affected dentin with different photosensitizers and its adhesive bond integrity to resin composite. Photodiagnostics Photodyn Ther 2020;31:101865. DOI: 10.1016/j.pdpdt.2020.101865.
13. Al Deeb L, Bin-Shuwaish MS, Abrar E, et al. Efficacy of chlorhexidine, Er Cr YSGG laser and photodynamic therapy on the adhesive bond integrity of caries affected dentin. An in-vitro study. Photodiagnostics Photodyn Ther 2020;31:101875. DOI: 10.1016/j.pdpdt.2020.101875.
14. Sitzia-Sazhoyn HB, de Oliveira MS, da Silva PP, et al. Does photodynamic therapy with methylene blue affect the mechanical properties and bond strength of glass-fiber posts in different thirds of intraradicular dentin? Photodiagnostics Photodyn Ther 2020;30:101673. DOI: 10.1016/j.pdpdt.2020.101673.
15. Alkhudhairy F, Vohra F, Naseem M, et al. Adhesive bond integrity of dentin conditioned by photobiomodulation and bonded to bioactive restorative material. Photodiagnostics Photodyn Ther 2019;28:110–113. DOI: 10.1016/j.pdpdt.2019.08.014.
16. Alkhudhairy F, Naseem M, Ahmad ZH, et al. Influence of photobiomodulation with an Er:Cr:YSGG laser on dentin adhesion bonded with bioactive and resin-modified glass ionomer cements. J Appl Biomater Funct Mater 2019;17(4):228080019880691. DOI: 10.1177/228080019880691.
17. Alkhudhairy F, Alkherafi A, Bin-Shuwaish M, et al. Effect of Er:Cr:YSGG laser and ascorbic acid on the bond strength and microleakage of bleached enamel surface. Photomed Laser Surg 2018;36(6):431–438. DOI: 10.1089/pho.2018.4437.
18. Alkhudhairy F, Vohra F, Naseem M. Influence of Er:Cr:YSGG laser dentin conditioning on the bond strength of bioactive and conventional bulk-filling restorative material. Photobiomodulation, Photomedicine, Laser Surg 2020;38(1):30–35. DOI: 10.1089/pho.2019.4661.
19. Alkhudhairy F, Al-Johany SS, Naseem M, et al. Dentin bond strength of bioactive cement in comparison to conventional resin cement when photosensitized with Er:Cr:YSGG laser. Pakistan J Med Sci 2020;36(2):85–90. DOI: 10.12669/pjms.36.2.1284.
20. Sirisha K, Avishankar Y, Kamalakumari P, et al. Validity of bond strength tests: a critical review-part II. J Conserv Dent 2014;17(5):420. DOI: 10.4103/0972-0707.139823.
21. Sirisha K, Rambabu T, Shankar YR, et al. Validity of bond strength tests: a critical review: part I. J Conserv Dent 2014;17(4):305–311. DOI: 10.4103/0972-0707.136340.
22. Alkhudhairy F. Dentin conditioning using different laser prototypes (Er:Cr:YSGG; Er:YAG) on bond assessment of resin-modified glass ionomer cement. J Contemp Dent Pract 2020;21(4):426–430. DOI: 10.5005/jp-journals-10024-2807.
23. Sitzia-Sazhoyn HB, Pereira da Silva P, Silva de Oliveira M, et al. Effect of photodynamic therapy on the mechanical properties and bond strength of glass-fiber posts to endodontically treated intraradicular dentin. J Prostheth Dent 2018;120(2):317.e1–317.e7. DOI: 10.1016/j.prosdent.2018.05.009.
24. Sitzia-Sazhoyn HB, Silva PP, Oliveira ME, et al. Influence of curcumin photosensitizer in photodynamic therapy on the mechanical properties and push-out bond strength of glass-fiber posts to intraradicular dentin. Photodiagnostics Photodyn Ther 2019;25:376–381. DOI: 10.1016/j.pdpdt.2019.01.025.
25. Chou J-C, Chen C-C, Ding S-J. Effect of Er:Cr:YSGG laser parameters on shear bond strength and microstructure of dentine. Photomed Laser Surg 2009;27(3):481–486. DOI: 10.1089/pho.2008.2282.
26. Ekworapoj P, Sidhu SK, McCabe JF. Effect of surface conditioning on adhesion of glass ionomer cement to Er, Cr:YSGG laser-irradiated human dentin. Photomed Laser Surg 2007;25(2):118–123. DOI: 10.1089/pho.2006.204.
27. Sakr OM. Microshear bond strength of bioactive restorative materials to dentin. Int J Dent Sci Res 2018;6(4):90–94. DOI: 10.12691/ijdsr-6-4-3.
28. Alkhudhairy F, Naseem M, Ahmad ZH, et al. Efficacy of phototherapy with different conventional surface treatments on adhesive quality of lithium disilicate ceramics. Photodiagnostics Photodyn Ther 2019;25:292–295. DOI: 10.1016/j.pdpdt.2019.01.015.