

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

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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 cemento-enamel 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, admixed 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.¹ 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.^{2,3} 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.^{2,4} Initially, glass ionomer cements (GICs) were widely used, since, they showed better physiochemical bonding to dentin and better bond integrity compared to adhesive resins.⁵ 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.⁶

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.⁷ However, available evidence indicates that RMGIC requires conditioning of tooth structure prior to restoration to improve bond integrity,^{4,8} whereas other lab-based studies have suggested that surface treatment of dentinal structure is not critical to improve bond values.^{7,8} Different conditioning regimes are used

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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

to remove smear layer.⁵ 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.⁹

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).^{10,11} PDT activates photosensitizers (PS) resulting in reactive oxygen species (ROS) accountable for smear layer removal and bacterial lysis.¹¹ PDT with different PS has recently been used by Alrahlah et al.,¹²

and Al Deeb et al.,¹³ on carious dentin structure with favorable outcomes. Similarly, Strazzi-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 poly-vinyl pipes (3 mm radius) up to cements/enamel 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 phased 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 dentin 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 50× 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 \pm SD (MPa)	p value*
Fuji II LC RMGIC	Group I: Methylene blue photosensitizer (MBP)	13.52 \pm 1.22 ^A	<0.05
	Group II: Curcumin photosensitizer (CP)	14.88 \pm 1.01 ^A	
	Group III: Er,Cr:YSGG laser (ECYL)	18.22 \pm 2.07 ^B	
	Group IV: Surface conditioner polyacrylic acid (PAA) (control)	19.55 \pm 1.84 ^B	

^{A,B}Indicate a statistically significant difference (Tukey multiple comparison test) ($p < 0.05$)

*Showing significant difference among study groups (ANOVA)

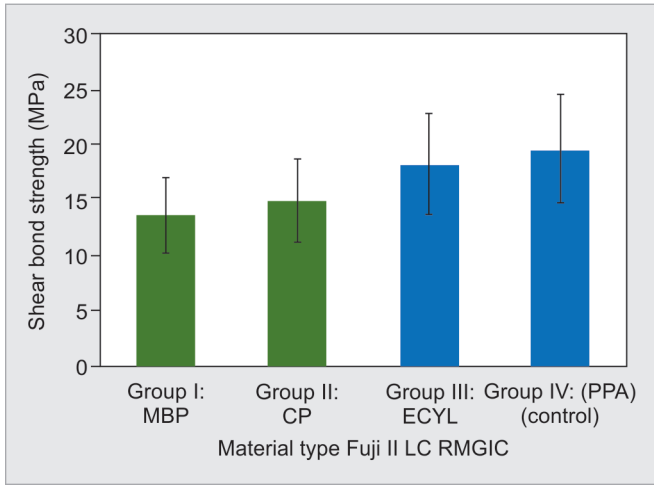


Fig. 1: Bar chart with standard error (SE) lines among experimental groups. MBP, methylene blue photosensitizer; CP, curcumin photosensitizer; ECYL, Er,Cr:YSGG laser; PAA, polyacrylic acid

Table 2: Percentages of different failure types among the experimental groups

Failure type (%)	Group I	Group II	Group III	Group IV
Adhesive	80	70	20	10
Cohesive	10	10	20	40
Admixed	10	20	60	50

Fracture analysis of debonded surface revealed that groups in which PDT was used as surface conditioner presented 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.^{20,21} 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.^{16,22}

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.⁵ 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. MBP is cationic in nature,

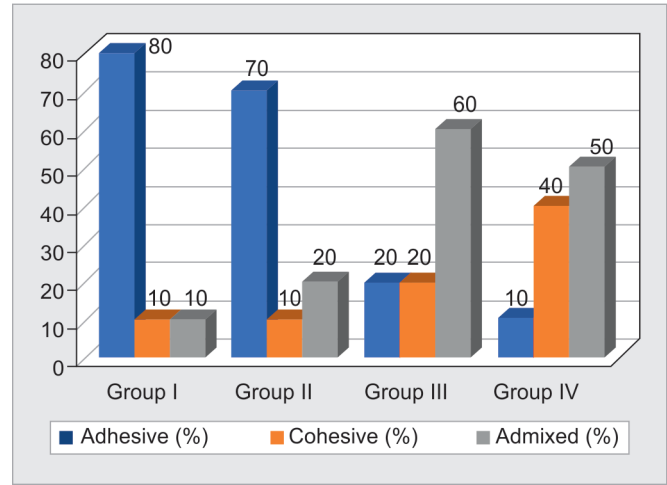


Fig. 2: Multiple bar chart demonstrating failure mode among investigational groups

with affinity for anionic molecule like phosphorus in hydroxyapatite of dentin.^{14,23} This affinity would have led to an imbalance in the calcium/phosphorus ratio resulting in precipitation between dentin and RMGIC and compromising bond integrity.²³ Moreover, the hydrophilic nature of MBP and curcumin at this concentration may have allowed for water sorption causing bond values to deteriorate.^{14,24} Similarly, CP when activated results in significant changes in dentin surface, as it does not lead to formation of singlet oxygen (O_2); but rather, forms hydrogen peroxide (H_2O_2) which on breakdown results in H_2O on the dentin surface, hence compromising bond values.²⁴

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.¹⁰ 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.^{7,25} 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.¹⁰ and Ekworapoj et al.²⁶ However, work by Jordehi et al.⁷ and Sakr²⁷ 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.¹

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.²⁶ 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.²⁸

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 PA. 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.

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