ORIGINAL RESEARCH

Dentin Conditioning Using Different Laser Prototypes (Er,Cr:YSGG; Er:YAG) on Bond Assessment of Resin-modified Glass Ionomer Cement

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Abstract

Aim: The aim of this study was to evaluate and compare various conditioning regimes (lased and conventional) on shear bond strength (SBS) of resin-modified glass ionomer cement (RMGIC) bonded to dentin.

Materials and methods: Sixty non-carious intact maxillary molars were cleaned, isolated, and randomly divided into six groups ($n = 10$). Before randomization, the dentin surface was exposed and finished. Samples in group I were conditioned using Er,Cr:YSGG laser (ECYL). Specimens in group II were conditioned using Er:YAG laser (EYL), and the dentin surfaces of specimens in group III and group IV were conditioned using cavity conditioner and K930. Similarly, the samples in group V and group VI were surface treated using 17% EDTA and total etch. All samples were bonded with RMGIC following conditioning regime. For SBS testing, the samples were placed in universal testing machine. A fracture analysis of debonded surfaces was evaluated using stereomicroscope at 40× magnification. Means and standard deviations (SDs) were calculated using analysis of variance (ANOVA) and Tukey's *post hoc* test at a significant level of $p < 0.05$.

Results: The maximum bond strength values were observed in group VI total etch (23.85 ± 3.67). The lowest bond strength was displayed in lased dentin group II conditioned by EYL (11.65 ± 2.77). Dentin conditioned with ECYL, cavity conditioner, K930 conditioner, and 17% ethylenediaminetetraacetic acid (EDTA) were found to be comparable, $p > 0.05$. Cohesive failure was dominant among experimental groups.

Conclusion: Er,Cr:YSGG laser has a potential to be recommended for dentin conditioning prior to application of RMGIC.

Clinical significance: Dentin conditioning enhances adhesion of RMGIC for improved prognosis and treatment outcome.

Keywords: Bond integrity, Er,Cr:YSGG, Er:Yag, Resin-modified glass ionomer cement, Surface conditioning.

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Introduction

Premature restorative failure is a foremost concern in clinical dentistry. The failure is a reason of weak bond between the substrate and restorative interface resulting in poor prognosis and treatment outcome.[1] The goal to find an ideal restorative material led to the evolution of resin-modified glass ionomer cement (RMGIC). A typical RMGIC consists of 80% fluoro-aluminium silicate in the form of glass ionomer cement (GIC) with polyacrylic acid (PAA) and 20% light-polymerized resin hydroxy-ethylmethacrylate (HEMA) or bisphenol A-glycidyl methacrylate (Bis-GMA) in the form of methacrylate.[2]

Resin-modified glass ionomer cements are hybrid materials and have characteristics better than conventional GIC. The properties of RMGIC range from better esthetics, improved handling, increased working time, and higher moisture resistance.[3] However, a controversy exists in the literature regarding the adhesion of GICs to dentin. Some studies suggest that RMGIC adheres to the tooth physiochemically without the need of conditioning,[4,5] whereas other studies have stated that conditioning of dentin is necessary to improve bond strength values.[2,6]

Dentin conditioners in the form of PAA, cavity conditioners, phosphoric acid, and EDTA have been documented to improve bond durability and strength when applied prior to RMGIC.[6,7] The use of conditioners removes smear layer, demineralizes, and makes dentin surface more receptive for bonding.[8] Moreover, conditioning favors bonding of RMGIC with dentin both mechanically and chemically.[4]

Alternatively, the use of ECYL and EYL for enamel/dentin and dental ceramics conditioning has exhibited convincing and favorable results.[9–12] Er,Cr:YSGG laser working at the wavelength of 2,780 nm open dental tubules removes smear layer resulting in micro-retentive dentinal pattern.[13,14] Moreover, EYL ablates dentin structure without thermal damage at 2,940 nm wavelength which facilitates adhesion of restorative material.[15,16]

To our knowledge from indexed literature, scarce evidence exists on the use of ECYL and EYL as dentin conditioner bonded with RMGIC. Moreover, limited data on comparison of conventional conditioning regimes with ECYL and EYL have been documented. It is hypothesized that dentin conditioned with cavity conditioner (control) prior to RMGIC will exhibit bond strength values comparable with ECYL and EYL. Therefore, the aim of this study

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was to evaluate and compare various conditioning regimes (lased and conventional) on SBS of RMGIC bonded to dentin.

Materials and Methods

Sixty non-carious, unrestored, intact maxillary third molars were collected in a period of 1 year as a bonding substrate and were stored in 0.4% sodium azide solution (NaN_3) (Merck, Germany). The specimens were cleaned with periodontal scaler and curette (Perio Soft-Scaler; Kerr Dental, Denmark) to remove debris and inorganic remnants and stored in chloramine T trihydrate solution (Merck) for 1 week following storage in distilled water at 4°C until use.

The samples were embedded vertically in self-cure acrylic resin (Opti-cryl, South Carolina, Columbia) up to cement-o-enamel junction within polyvinyl pipes of 4 mm diameter. Model trimmer (IsoMet; Buehler, USA) under irrigation was used to wet ground the occlusal surface, to expose dentinal surface finished with silicon carbide grinding disks 1,200 grits (Buehler, Great Britain, UK). Based on the conditioning regimes, the samples were randomly classified into six groups ($n = 10$ each)

Group I: The samples were conditioned with ECYL (Waterlase; Biolase Technology, San Clemente, CA) at 0.5 W and 30 Hz frequency from 2 mm distance in a noncontact position for a duration of 60 seconds using a laser tip MZ8. The air/water pressure was 65%/55%.

Group II: The surface of bonded specimen was treated using EYL (Kavo Key Laser 2; Kavo Corp., Biberach, Germany). The laser was used in a circular motion at 350 mJ of energy and 2 Hz of pulse repetition for a duration of 60 seconds at 2 mm distance.

Group III: The surface of the samples was conditioned using a cavity conditioner (GC America, Inc, Latin America) applied for a duration of 10 seconds and washed and air-dried without desiccation.

Group IV: Bonded dentinal surface of specimens was conditioned using K930 conditioner (GC America, Inc, Latin America) for 15 seconds and washed and air-dried for 3 seconds without desiccation.

Group V: Dentinal surface of the specimens was surface treated with 17% EDTA (Pyrex Pharmaceutical, USA) for 30 seconds and washed for 15 seconds and blow-dried without desiccation.

Group VI: All samples in this group were exposed with 37% phosphoric acid (Aqua Etch, India) for 10 seconds and rinsed thoroughly for 10 seconds. Bonding agent (Prime & Bond NT; Dentsply, Sirona, USA) was applied for 10 seconds and air-dried and light cured (Bluephase G2; Ivoclar Vivadent, Schaan, Liechtenstein) 10 seconds.

All samples were now bonded with RMGIC Fuji II LC (GC Corporation, Tokyo Japan) and mixed and applied incrementally (2-mm-thick increment) in accordance with the manufacturer's instructions and light cured for 20 seconds (Bluephase G2; Ivoclar Vivadent). A protective varnish was applied, and the specimens were stored in distilled water for 24 hours followed by SBS testing (Table 1).

SBS Testing of Specimens

Specimens were placed at the lower base of universal testing machine (Lloyds LF-Plus; Ametek, Inc., Great Britain, UK) so that the bonded base cylinder was parallel to the direction of force at 0.5 mm/minute crosshead speed until fracture. The load required to debond was recorded in Newton but calculated in megapascals.

Table 1: Materials used in this study

Materials	*Manufacturer*	*Composition*
Fuji II LC	GC Corporation, Tokyo Japan	Fluoro-aluminium silicate glass, polyacrylic acid, HEMA
Cavity conditioner	GC America, Inc.	20% polyacrylic acid, $AlCl_3$
K930 conditioner	GC America, Inc.	12% citric acid, 4% $AlCl_3$
17% EDTA	Pyrex Pharmaceutical	17% poly-amino carboxylic acid
Optibond Solo Plus (total etch)	KaVo Kerr, West Collins, Orange, CA	Bisphenol glycidyl methacrylate, glycerol DMA, glycerol phosphate DMA, DMAs, ethanol silicone oxide, barium borosilicate, and sodium hexafluoro-silicate

DMA, dimethylarsenate

Fracture Analysis

Fracture surfaces of debonded specimens were analyzed under stereomicroscope (SR; Zeiss, Oberkochen, Germany) at 40× magnification by a single examiner to minimize bias. The modes of failure of samples were classified into adhesive (substrate–adhesive interface), cohesive (in the materials or in substrate itself), and admixed (involving both interfaces of material and substrate). Failure sites were not statistically examined.

Statistical Assessment

Normality of the data were assessed using Kolmogorov–Smirnov test, and equality of variance assumptions was evaluated by modified Levene test. Means and standard deviations were calculated using ANOVA and Tukey's *post hoc* test at a significant level of $p < 0.05$.

Results

Normal distribution of data was observed in this study. For bond strength values, ANOVA showed a significant difference among all the experimental groups ($p < 0.05$). The maximum bond strength values were observed in group VI total etch (23.85 ± 3.67). The lowest bond strength was displayed in lased dentin group II conditioned by EYL (11.65 ± 2.77). Dentin conditioned with ECYL in group I, cavity conditioner in group III, K930 conditioner in group IV, and 17% EDTA in group V was found to be comparable, $p > 0.05$ (Table 2 and Fig. 1).

Fracture analysis of debonded specimen revealed cohesive failure among group I, group III, group IV, group V, and group VI. Moreover, the adhesive failure type was observed in group II conditioned with EYL (Table 3 and Fig. 2).

Discussion

The present laboratory-based study was constructed on the hypothesis that conventional conditioning of dentin using cavity conditioner will exhibit bond integrity similar to lased dentin (ECYL and EYL). Interestingly, the present *in vitro* study revealed that conditioning of dentin with ECYL exhibited comparable SBS with

Table 2: Using analysis of variance (ANOVA) and Tukey's multiple comparison test for the comparison of means and SD for bond strength values among study groups

Material type	*Type of conditioning*	*Mean ± SD*	*p value**
Fuji II LC (RMGIC)	Group I: Er,Cr:YSGG laser (ECYL)	18.25 ± 3.22[a]	< 0.05
	Group II: Er:YAG laser (EYL)	11.65 ± 2.77[b]	
	Group III: cavity conditioner (control)	17.54 ± 2.93[a]	
	Group IV: K930 conditioner	18.33 ± 2.52[a]	
	Group V: 17% ethylenediaminetetraacetic acid (EDTA)	19.25 ± 3.21[a]	
	Group VI: total etch	23.85 ± 3.67[c]	

Different superscript letters in individual materials indicate statistical differences ($p < 0.05$); *Showing significant difference among study group (ANOVA)

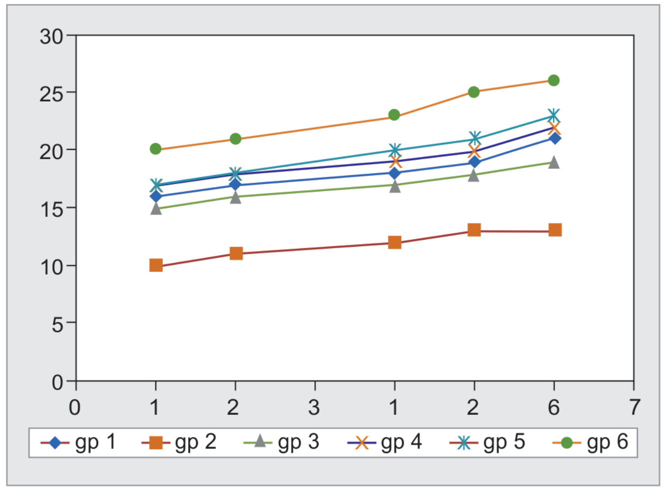

Fig. 1: Line chart displaying shear bond strength among the investigational groups. Group I, Er,Cr:YSGG laser (ECYL); group II, Er:YAG laser (EYL); group III, cavity conditioner (control); group IV, K930 conditioner; group V, 17% ethylenediaminetetraacetic acid (EDTA); group VI, total etch

dentin conditioned with 17% EDTA, cavity conditioner, and K930 conditioner. While dentin conditioned with EYL displayed low bond integrity with RMGIC. Therefore, the hypothesis of this study was partially accepted. In this study, the SBS values were assessed using a universal testing machine as the method is homogeneous, easy to use, and displays quantitative data for comparative analysis. Furthermore, the test is beneficial for depth profiling and screening of RMGIC and GIC.[17,18]

The bonding of restorative material to dentin structure is complex. Conditioning of dentin preceding RMGIC modifies the dentin by making it receptive to bond, eliminates smear layer, and enhances surface wettability.[11] In this study, dentin conditioned with EYL exhibited the lowest bond strength (11.65 ± 2.77) among all investigational groups. Er:YAG laser is well absorbed by the dental tissues and the wavelength on which EYL works coincide with absorption band of water (approximately 3 μm) and hydroxyapatite crystals of dentin.[19] Evidence dictates that low bond scores shown by EYL can be attributed to heat production resulting in structural damage to dentin.[19,20] Moreover, excessive heat may result in denaturation of the collagen network preventing diffusion of monomer compromising bond integrity.[21] It can be also estimated that thermal effect by EYL may compromise interdiffusion zone formation between RMGIC and dentin substrate.[20,21] The finding of low bond score by EYL in this study was in harmony with the work by De Souza-Gabriel et al.[19] However, studies by Hibst and Keller[22] and Visur et al.[23] argue that heat produced by EYL does not damage the dentin and propagates into pulp. In contrast, conditioning of dentin with ECYL (18.25 ± 3.22) exhibited bond strength comparable with cavity conditioner (17.54 ± 2.93), K930 (18.33 ± 2.52), and 17% EDTA (19.25 ± 3.21). In this study, ECYL was used at 0.5 W and 30 Hz, and these laser parameters below ablation threshold favor ionic exchange between dentin and RMGIC through the formation of an intermediary layer.[14,24] Moreover, these low energy density parameters increase the content of phosphorous, calcium, and magnesium on the tooth surface, thereby improving adhesion.[24] However, the work by Jordehi et al.[25] advocates that laser irradiation of dentin decreased SBS values in GIC. Although findings of our study was in line with Garbui et al.,[24] these heterogeneous outcomes can be attributed to the use of different laser parameters, type of testing (SBS or microtensile bond strength), thick ness of dentin, form of dentin (human or bovine), irradiation time and distance, and type of material.

Finding of no significant difference was found with cavity conditioners (17.54 ± 2.93), K930 (18.33 ± 2.52), and 17% EDTA (19.25 ± 3.21) with Fuji II LC. It has been demonstrated in previous studies that PAA in the form of cavity conditioner enhanced bond strength by creating irregularities on the substrate surface and $AlCl_3$ in cavity conditioner stabilized dental collagen for easy penetration of HEMA in RMGIC during dentin demineralization.[4,26] Moreover, citric acid used as dentin conditioning agent was first used by Hotz et al.[27] In this study, 12% citric acid was used in the form of K930 exhibiting better SBS compared with cavity conditioner. Documented evidence suggests that K930 at low pH (0.82) cleans and chelates both the surface and the cement.[4] In addition, K930 at decreased pH dissolves the smear layer increasing the molecular interaction between the surface substrate and poly anions in the cement, thereby improving adhesion.[28] The finding of this study was in concurrent with the work of Terata et al.[29] However, the work by Powis et al.[30] contends against the use of K930 as conditioner since its use dissolves the calcium- and phosphate-rich material in dentin and denatures the dentinal collagen. In authors' opinion, diversity in results can be credited to concentration and duration of citric acid applied, type of material RMGIC/GIC, and nature of dentin superficial or deep.

Dentin conditioned with 17% EDTA displayed mean bond strength value of 19.25 ± 3.21. A possible explanation to this outcome can be ascribed to its less aggressive nature to decalcify dentin creating low and thin resin tags, widening of dental orifice, and formation of thin hybrid layer without dissolving dentinal proteins.[31] This analysis is validated by Rai et al.,[6] asserting that 17% EDTA used as a conditioner on dentin presented better bond integrity with three different types of RMGIC. The highest bond strength values were noted in the total etch group. This outcome was in concurrent with the work by Poggio[32] and Imbery et al.[2] Improved removal of smear layer and better opening of dentinal tubules resulting in effective penetration of resin monomer forming a healthier diffusion zone between dentin and cement ensuing both mechanical and chemical interlocking are some factors contributing to highest bond scores in this group.

Table 3: Percentage distribution of modes of failure

Failure type (%)	*Group I: Er,Cr:YSGG laser (ECYL)*	*Group II: Er:YAG laser (EYL)*	*Group III: cavity conditioner (control)*	*Group IV: K930 conditioner*	*Group V: 17% EDTA*	*Group VI: total etch*
Adhesive	10	80	20	10	–	20
Cohesive	60	10	50	70	60	70
Admixed	30	10	30	20	40	10

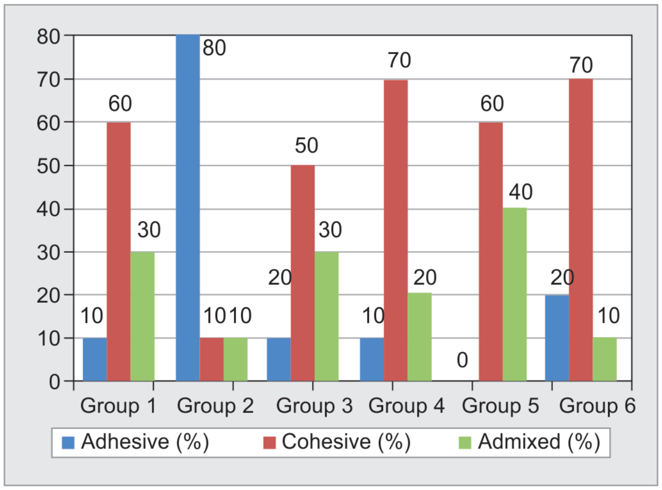

Fig. 2: Multiple bar chart showing fracture analysis among different groups. Group I, Er,Cr:YSGG laser (ECYL); group II, Er:YAG laser (EYL); group III, cavity conditioner (control); group IV, K930 conditioner; group V, 17% ethylenediaminetetraacetic acid (EDTA); group VI, total etch

Majority of failure type among experimental groups was cohesive. While adhesive failure was noted in the EYL group only. The type of failure in different experimental groups corresponded to SBS scores. Cohesive failure is found to be common in RMGIC due to porosity within the cement itself. It is expected that these porous areas within the material act as stress concentrators from where the fracture is instigated.

Within the limitations of this study, the greatest drawback of the current *in vitro* study was not performing micromorphological evaluation of the conditioned dentin surface and dispersive spectroscopy of the debonded surface. The concept of conditioning dentin with different laser prototypes is a novel concept and needs further clinical and lab-based evaluation under different laser parameters. Element analysis along with material mapping is proposed for RMGIC on dentin conditioned with ECYL and EYL. Resin-modified glass ionomer cement bonded on lased dentin under short- and long-simulated aging needs to be investigated. Scope on the use of ECYL for surface conditioning is huge as it offers comfort of application intra-orally, patient and dentists ease, and nominal contamination. Therefore, further researches for progress of this technique are suggested.

Conclusion

ECYL has a potential to be recommended for dentin conditioning prior to application of RMGIC.

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