Original Article

Influence of Diode Laser on the Bond Strength of Self-Etching Adhesive Systems to Human Dentin: An *in vitro* Study

Abstract

Introduction: The treatment of dental tissues before adhesive restorative procedures is an important step in the bonding protocol and determines the clinical success of restorations. **Aim:** The aim of this study is to evaluate *in vitro* the influence of diode laser on the shear bond strength of one- and two-step self-etch (SE) adhesives to dentin when the laser is applied over the adhesives before photopolymerization. **Methodology:** About 20 freshly extracted noncarious intact maxillary premolars were collected, and the buccal and lingual surfaces of the tooth were ground with the help of diamond disk under water coolant till dentin was exposed. The specimens were divided into two groups of 10 each. Buccal surfaces of all the specimens were exposed to diode laser before light curing (test/experimental group) act as control group. In Group I, Clearfil SE with laser was used on the buccal surface, whereas in Group II, G-bond SE adhesive with laser was used on the buccal surface. Shear bond test was measured using an universal testing machine and the values were obtained in megapascals (MPa). **Results:** $P < 0.05$ was considered statistically significant. According to the results, it was found that the mean bond strength values of the laser-treated groups were significantly higher than groups not treated with laser. **Conclusion:** Within the limitations of this study, it can be concluded that mean bond strength Clearfil SE with and without laser was significantly higher than G-bond with and without laser values.

Keywords: *Clearfil self-etch, diode laser, G-bond, shear bond strength, maxillary premolars*

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Introduction

Bonding to dentin is a greater challenge and has been extremely studied because of the difficulty of a less reliable substrate.[1,2] The dentin is composed of a heterogeneous structure containing approximately 70% hydroxyapatite, 18% organic material, and 12% collagen.[3] The organic and inorganic components are unevenly distributed in intertubular and peritubular dentin. Moreover, the dentin is highly permeable tissue with numerous dentinal tubules that extend radially from the pulp throughout the entire thickness of dentin.[4] Therefore, several factors account for the difference in bonding mechanism of enamel and dentin.

The basic mechanism of bonding to enamel and dentin is essentially an exchange process involving replacement of minerals removed from hard dental tissues as a result of acid etching by resin monomers. When these monomers polymerize, they become micromechanically interlocked in the porosities thus created. Conventional adhesive systems are based on acid etching followed by a conditioning step with the primer and the application of adhesive resin or systems that combine the primer and the bonding agent into one application. The treatment of dental tissues before adhesive restorative procedures is an extremely important step in the bonding protocol and determines the clinical success of restorations.

Recently, many new adhesive systems have been introduced. Current developments in adhesive systems have focused on simplifying the application methods by decreasing the time and steps required for placement. These adhesive systems include single bottle systems which combine priming and bonding in one-step and self-etching priming systems, which combine conditioning and priming in one-step, self-etch (SE) adhesive systems which combine priming and bonding.[5,6]

Clearfil SE bond has been reported as a two-step self-etching primer adhesive

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system that produces high bond strength to normal dentin, theoretically because of simultaneous collagen fiber network exposure and monomer infiltration, which may create a sufficient retentive strength and an adequate seal.

G-bond is a 7th Generation (single component) adhesive with a combination of phosphoric acid ester monomer and 4-META adhesive technology creating superior adhesion to enamel, in addition to providing a chemical and mechanical seal to dentin referred to as the Nano Interaction Zone.

During the last few years, the use of laser techniques has dominated the operative world as an alternative to different traditional methods. LASER is an acronym for "Light Amplification by the Stimulated Emission of Radiation." Lasers emit light energy that can interact with biologic tissues, such as tooth enamel, dentin, gingiva, or dental pulp. The interaction is the effect of the particular properties of laser light including monochromaticity, coherence, and collimation.

The diode laser is the most frequently used in dentistry due to its reliability, versatility, and convenience. The diode laser is a laser produced by stimulation of gallium and arsenide, with or without aluminum or indium. It has a wavelength of 800–1064 nm. It can be used for a multitude of dental procedures which are predominantly soft-tissue surgeries, periodontal pocket therapy, peri-implantitis and can also be used in endodontics for root canal disinfection and in laser-assisted tooth whitening.

In 1999, Gonglaves *et al*. developed a technique of irradiating the dentin substrate with neodymium-doped yttrium aluminum garnet (Nd:YAG) laser which promoted fusion and recrystallization of dentinal hydroxyapatite in the presence of resin monomer, thereby developing new layer of dentin tissues and adhesive system joined by the action of the laser.[7]

Most researchers found significantly higher bond strength values for total etch and SE systems receiving Nd:YAG before polymerization. The influence of diode laser on irradiation of SE adhesives has not yet been evaluated.

Thus, the aim of the study is to evaluate the influence of the diode laser on the bond strength of self-etching adhesives to human dentin.

The null hypothesis for this study was that there is no difference in shear bond strength values on or between Clearfil SE and G-bond on the application of diode laser.

Methodology

About 20 freshly extracted noncarious intact maxillary premolars were collected, and the teeth were cleaned thoroughly, sterilized, and stored in distilled water. The buccal and lingual surfaces of teeth were ground with the help of a diamond disc under water coolant till dentin was exposed. A mold was prepared with the help of modeling wax in the form of rectangular cubes. Later, the modeling wax was replaced with cold cure acrylic resin in all the 20 teeth till cementoenamel junction. Test area was delimited to a circle of 3-mm × 3-mm diameter with the help of nail varnish on both buccal and lingual surfaces of all the specimens.

The specimens were divided into two groups of 10 each [Figure 1]. After the application of respective bonding agents, buccal surfaces of all the specimens were exposed to diode laser [Figure 2] before light curing (test/experimental group), while the lingual surfaces were not exposed to lasers.

- Group I – Clearfil SE two-step SE adhesive resin [Figure 3]
  - Subgroups IA – Buccal (with laser treatment)
  - Subgroups IB – Lingual (without laser treatment).
- Group II – G-bond one-step SE adhesive resin.
  - Subgroups IIA – Buccal (with laser treatment)
  - Subgroups IIB – Lingual (without laser treatment).

Method of adhesive application

Group I – Clearfil SE (two-step SE adhesive).

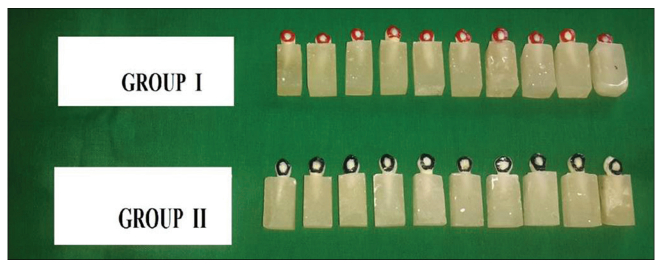

Figure 1: Specimens divided into groups


Figure 2: Diode laser, armamentarium

Figure 3: Clearfil self-etch bond

Subgroup A – Buccal (IA): Clearfil SE primer was applied on the buccal surface for 20 s using applicator tips. Later, the primer was air dried and the bonding agent was applied evenly according to the manufacturer's instructions. Picasso diode laser unit with a wavelength of 810 nm, power of 1.5 W, and pulse rate of 1.5 pulses/s with a noncontact tip of 300-μm diameter was used in this study.

The laser was applied with freehand in noncontact mode for 60 s. During laser application, laser tip was held perpendicular (90° angle) to the specimen's buccal surface at a distance of 5 mm. Self-cure acrylic resin was used to make a device specially for the purpose of maintaining the distance between the laser tip and the dentin surface of the specimen. Later, polymerization was done with LED curing light unit for 20 s [Figure 4a-g].

Subgroup B – Lingual (IB): Clearfil SE primer was applied on lingual surface for 20 s using applicator tips. The primer was then air dried and the bonding agent was applied evenly according to the manufacturer's instructions, followed by polymerization with LED curing light unit for 20 s.

Group II – G-bond adhesive resin (one-step SE adhesive) [Figure 5].

Subgroup A – Buccal (IIA): Application of G-bond SE adhesive according to the manufacturer's instructions followed by irradiation with diode laser in noncontact mode for 60 s as mentioned above and then polymerization with LED curing light unit for 20 s.

Subgroup B – Lingual (IIB): Application of G-bond SE adhesive according to the manufacturer's instructions and then polymerization with LED curing light unit for 20 s.

Restoration placement

After their respective treatments as mentioned above, a 3-mm × 3-mm plastic straw was used to place composite resin in small increments with each increment being polymerized with a LED curing light for 20 s. Later, the straw was incised, peeled, and removed leaving cylinder of composite bonded to the treated surface which was then light polymerized for an additional 60 s. The specimens were then immersed in distilled water for 48 h.

A jig measuring 4 × 1/8 inch was attached to Instron universal testing machine. The specimens were then individually mounted on universal testing machine [Figure 6] for debonding at a crosshead speed of 0.5 mm/min. The shear bond strength values obtained were then subjected to statistical analysis.

Results

All the analysis was done using SPSS version 18 (Statistical package for social sciences developed by IBM). $P < 0.05$ was considered statistically significant. Comparison of values obtained between surfaces treated with and without laser was done using paired *t*-test and ANOVA with *post hoc* Tukey's test according to Table 1.

Table 1: Intergroup comparison of mean shear bond strength values of Groups I and II treated with and without laser

	Mean (SD)		*P* (<0.05; significant)
	Subgroup A	Subgroup B	
Group I	22.47 (2.82)	21.10 (2.50)	0.006; significant
Group II	14.74 (1.96)	14.12 (1.79)	0.021; significant

Paired *t*-test. SD: Standard deviation

The mean value of shear bond strength in Group IA was 22.47 and Group IB was 21.10.

The mean value of shear bond strength in Group IIA was 14.74 and Group IIB was 14.12.

There was significant difference in mean shear bond strength values among all the four groups. *Post hoc* test table 2 showed that mean values of Group IA (22.47)

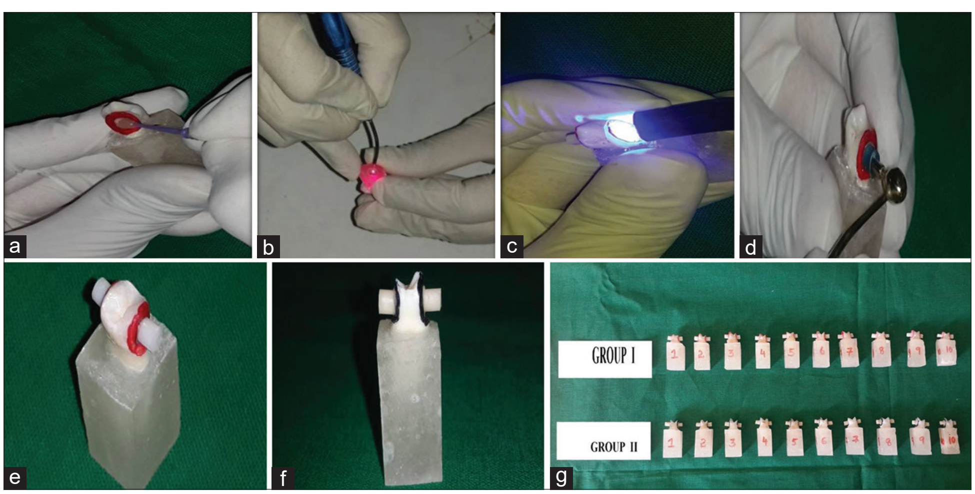

Figure 4: (a) Application of bonding agent on sample. (b) Application of diode laser using acrylic stopper device. (c) Curing bonding agent with led curing light. (d) Placement of straw and insertion of composite. (e) Samples after bonding with composite block occlusal view. (f) Samples after bonding with composite block proximal view. (g) Grouping of labeled specimens after restoring with composite blocks

Table 2: Intergroup comparison of mean shear bond strength values of Groups I and II treated with and without laser

	Group, mean (SD)				*P* (<0.05; significant)	*Post hoc* test
	Group IA	Group IB	Group IIA	Group IIB		
Bond strength	22.47 (2.82)	21.10 (2.50)	14.74 (1.96)	14.12 (1.79)	<0.001; significant	IA>IIA, IIB IB>IIA, IIB

ANOVA with *post hoc* Tukey's test. SD: Standard deviation

Figure 5: G-bond

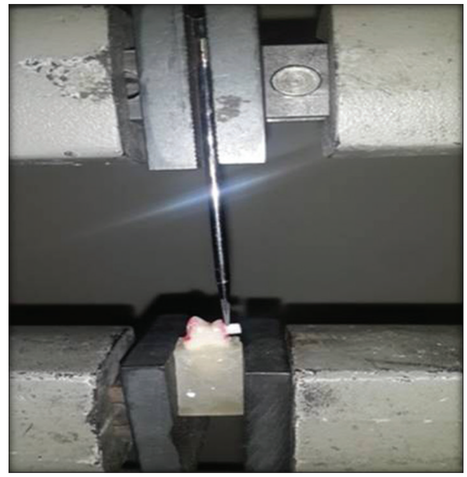

Figure 6: Specimen mounted on Instron machine for shear bond strength testing

was significantly higher than Group IIA and Group IIB. Similarly, Group IB (21.1) was also significantly higher than Group IIA and Group IIB.

Discussion

Dr. Buonocore, 50 years ago, described a concept where in etching enamel with phosphoric acid has been considered the gold standard for bonding the resin-based materials to tooth structure. The micromechanical nature of the interaction of adhesives with enamel is a result of the infiltration of resin monomers into the microporosities left by the acid dissolution of enamel and subsequent enveloping of the exposed hydroxyapatite crystals with the polymerized monomers.[8]

According to the results of this study, Clearfil SE a two-step SE adhesive showed a better bond strength when compared to the G-bond a one-step SE adhesive. This is in accordance with Foong *et al*. who conducted an *in vitro* study to compare microshear bond strengths to enamel of three all-in-one adhesive systems (Xeno III, G Bond, and One-Up Bond F) and one two-step self-etching priming system (Clearfil Protect Bond). According to their results, Clearfil Protect Bond demonstrated higher and more consistent bond strengths than Xeno III, G Bond, or One-Up Bond F.[9]

A meta-analysis on factors affecting the bond strength of self-etch adhesives by Vanajasan *et al*. also showed that two-step self-etch adhesive system showed a superior *in vitro* performance in comparison to one-step self-etch system.[10]

Clearfil SE Bond is a two-step mild self-etching primer adhesive system. The primer of Clearfil SE Bond contains 10-MDP as functional monomer dissolved in water and ethanol resulting in a pH around 2. On dentin, Clearfil SE Bond does not remove the smear layer but hybridizes it to the underlying dentin and impregnates smear plugs, thereby fixing them to the internal tubular walls. The bonding mechanism of Clearfil SE bond was therefore suggested to result from the simultaneous demineralization and infiltration of enamel and dentin to form a continuum in the substrate incorporating the smear plug in the resin tag.[11]

Besides simplifying bonding technique, the elimination of both rinsing and drying steps reduces the possibility of overwetting or overdrying as they have a negative effect on adhesion. Furthermore, the presence of the highly hydrophilic 10-MDP monomer is believed to improve the wetting to moist tooth surface. In addition, 10-MDP has two hydroxyl groups that may chelate the calcium ions of dentin. Moreover, the residual hydroxyapatite around the exposed collagen fibrils remains available for additional chemical interaction with the functional monomers.[12]

The hydroxyapatite preservation within the submicron hybrid layer may can act as a receptor for additional chemical bonding which was found to be advantageous. Keeping hydroxyapatite around collagen may also protect the collagen against hydrolysis and thus early degradation of the bond. This could be some of the reasons of enhanced bond strength of Clearfil SE over G-bond in the present study.

The bond strength of G-bond was found to be low when compared to Clearfil SE in the present study. This is in accordance with a study by Monticelli *et al*., where phase separation among adhesive compositions was confirmed, as droplets entrapped during solvent evaporation from 2-hydroxyethyl methacrylate-free adhesives. This phenomenon could be explained by the evaporation of solvents such as ethanol and acetone, which affected the balance of solvents and resin monomer and caused water to separate from other compositions of the adhesive. Spherical blisters within the resin film may be the outcome of residual, free water not completely evaporated, and therefore, entrapped at the interfacial level.[13] The convergence of small blisters into larger ones tends to produce honeycomb structures that may jeopardize the bonded interface.[14]

Laser has been used for various applications in dentistry. In recent years, the use of laser for cavity preparation as well as for dentinal and enamel surfaces conditioning as an alternative method for acid etching is increasing.

In the present study, the applications of laser on SE adhesives gave a better result when compared to the nonlased group. This is in agreement with Gonglaves *et al*.[7] who recommended that Nd:YAG laser irradiation on dentin previously conditioned with adhesive system before polymerization promoted the development of new substrate, in which dentin and adhesive may be fused by action of the laser. Nd:YAG lasers promote denaturation of the organic components of dentin by heat generation, fusion, and recrystallization, thereby obliterating some dentinal tubules. Morphological alterations of the tooth substrate occur also because of reduction in the percentage of calcium and phosphate in the dentin structure, causing changes in the organic composition of hydroxyapatite, leading to its recrystallization.

According to the Franke *et al*. the immediate increase in bond strength could be because of the heat provided directly by laser irradiation, which could favor adhesive penetration and solvent evaporation.[15] It was also found that a warm air stream can also provide immediate increase in bond strength values which could explain the favorable results obtained with the laser irradiation technique.[16]

According to the Ramos *et al*. who conducted a study on the effect of erbium-doped yttrium aluminum garnet laser (Er:YAG) on bond strength to dentin of a self-etching primer and two single bottle adhesive systems concluded that Er:YAG laser adversely affects the bond strength in higher or lesser degree depending upon the adhesive system used.[17]

Vohra *et al*. conducted a study on the influence of Er:Cr: YSGG laser on adhesive strength and microleakage of dentin-bonded to resin composite. In this study, 40 third molars were prepared with conventional diamond wheel bur, and the other 40 were prepared with Er, Cr:YSGG laser (erbium, chromium-doped yttrium, scandium, gallium and garnet) (phototherapy); later, they were subgrouped and treated with total etch and SE. It was concluded from the study that use of etch and rinse dentin bonding regime in combination with Er: Cr: YSGG phototherapy dentin treatment had the potential for clinical application in comparison to conventional conditioning technique.[18] In the above study, the laser was used for preparation of dentin; however, no much evidence was available on the effect of Er: Cr:YSGG laser after application of bonding agent.

In the present study, we used diode laser as an alternative as it provides a near-infrared irradiation with parameters similar to those provided by Nd:YAG but with more attractive usage and availability, such as lower size, weight, and cost. Diode laser irradiation has been proposed for endodontic therapy and has been shown to increase the level of disinfection, as well as produce morphological changes that occlude dentin tubules, improving the seal of the root canal system.[19]

However, there are only few studies with regard to the effects of the diode laser in enhancing the bonding to the dental structures.

Hence, in the present study, when the diode laser was applied over the adhesives before polymerization, there must have been a formation of new layer where in both the dentin and adhesive are fused, resulting in enhanced bond strength when compared to the nonlased group. Local heat generation caused by laser irradiation may also cause a higher degree of conversion of the adhesives already infiltrating the dentin, especially if the diode laser wavelength is well absorbed by the adhesives.[20]

Therefore, the null hypothesis for this study that there is no difference in shear bond strength values on or between Clearfil SE and G-bond on the application of diode laser has been rejected.

Laser irradiation may represent one more step in dentin hybridization. However, further *in vivo* studies and research should be performed to investigate the underlying mechanism by which laser irradiation can promote increased bond strength values and also the longevity of the laser-treated hybrid layer.

Conclusion

Within the limitations of this study, it can be concluded that

1. Mean bond strength values of Clearfil SE to dentin with and without laser treatment were higher than G-bond groups with and without laser treatment
2. It was also found that diode laser significantly increased the bond strength to dentin substrate irrespective of Clearfil SE or G-bond.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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