



# Influence of phototherapy on bond strength and failure modes of enamel bonded to ceramic and metallic brackets with different surface treatment regimes

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## ABSTRACT

**Aim:** The aim of the current study was to assess efficacy of phototherapy on mode of failure and shear bond strength among different brackets in combination with dissimilar conditioning regimens on enamel surface.

**Material and methods:** Ninety maxillary premolars were arbitrarily assigned into six groups (n = 15 each) based on surface conditioning of enamel. Group 1 and group 2 surface treated with total etch + rinse. Group 3 and group 4 surface conditioned with Er,Cr:YSGG. Group 5 and group 6 surface treated with self-etching primer (SEP). Now based on the type of bracket bonded to enamel surface. Group 1, 3 and 5 were bonded to metallic brackets (MB). Similarly, group 2,4,6 were bonded to ceramic bracket (CB). All samples from each group were positioned in a universal testing machine for shear bond strength testing. Ten samples from each group were used to discover the sites of bond failure using ARI with stereomicroscope. The mean shear bond strength of six groups were compared by analysis of variance (ANOVA) and pairwise comparison between groups were analysed with the Post hoc Tukey test at a significance level of (p < 0.05).

**Results:** The maximum SBS values were displayed by group 1 total etch + rinse MB (14.84 ± 1.78) whereas the minimum shear bond strength values were exhibited by group 6 SEP CB (9.99 ± 0.91). Samples treated with total etch + rinse MB (14.84 ± 1.78) and group 3 Er,Cr:YSGG MB unveiled comparable bond strength (p > 0.05). Similarly, experimental group 2 total etch + rinse CB (12.52 ± 1.28) was found to be comparable to group 4 Er,Cr:YSGG CB (12.14 ± 4.12) (p > 0.05).

**Conclusion:** Enamel etched for bonding bracket with Er,Cr:YSGG phototherapy at (4.5 W and 30 Hz) displayed comparable bond strength to conventional Transbond XT independent on the type of brackets used.

## 1. Introduction

One of the most imperative aspect of orthodontic treatment has to be suitable bond strength between bracket and tooth surface [1]. To attain favourable bond strength, formation of micro-tags within the enamel is essential for resin-enamel adhesion [2]. Multiple conditioning regimes are available which modifies enamel surface. One is the conventional (total etch and rinse), based on acid etching of enamel resulting in surface alteration and improved surface energy, followed by application of primer and resin [2,3]. The traditional bonding system has an advantage of precise extended working time, improved physical characteristics and easy removal of excess adhesives [4,5]. However, there are studies which report conventional (total etch and rinse) system to be time consuming, prone to salivary contamination during bracket bonding, while etching with phosphoric acid damages and causes greater enamel loss [6,7].

A new etching system in combination of a primer and a conditioner has been recently introduced in orthodontics to simplify the bonding process and steps. These self-etching primers (SEP) are known to be less technique sensitive, require no water irrigation hence reduce salivary contamination and decrease the time required for removal of adhesive after bracket debonding [8,9]. Furthermore, since the primary aim of orthodontic treatment is to maintain integrity of enamel surface after orthodontic attachment removal, using SEP on enamel yields gentler and milder etch patterns [10,11]. However, controversy prevails among studies on bond strength of bracket bonded with SEP to exhibit low bond strength values compared to conventional (total etch and rinse) [12–15].

Recently, use of laser as phototherapy in treating dental and medical conditions have shown mounting interest [16]. Among lasers, Erbium, chromium-doped yttrium, scandium, gallium and garnet (Er,Cr:YSGG) phototherapy working at a wavelength of 2790 nm is known to be well

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absorbed by the dental hard tissues [17]. The laser is simple to use and is based on the principal of micro abrasion i.e., roughens the enamel and dentinal surfaces similar to acid etch technique. Current evidence suggests that increase in temperature by Er,Cr:YSGG phototherapy results in thermomechanical damage of the hard tissues improving bond strength by removing free radicals [18,19].

To our understanding from available literature, practise of Er,Cr:YSGG on enamel as surface conditioner alternate to conventional (total etch and rinse) is dubious and limited [20,21]. In addition, recent bonding regimens i.e. (total etch and rinse) and SEP on non-lased enamel surface bonded to ceramic and metallic bracket needs to be investigated. It is assumed that enamel lased with Er,Cr:YSGG phototherapy at (4.5 W and 30 Hz) and bonded with ceramic and metallic bracket will display comparable bond strength to conventional total etch and rinse bonded to different brackets. Hence, the purpose of the existing study was to evaluate mode of failure and shear bond strength amongst different brackets in combination with dissimilar conditioning regimens on enamel.

## 2. Material and methods

The current study adhered to the checklist for reporting in-vitro study (CRIS) guidelines. Ninety maxillary premolars from an age group of 18–25 years were collected in a period of six months, extracted due to orthodontic purpose. Tooth were examined macroscopically and only extracted tooth free from carious lesion, attrition, restoration, structural abnormality and having intact buccal surface were included in the final sample. All samples were disinfected in a thymol solution of 4% (weight/volume) at room temperature for one week to avoid cross infection. Moreover, the samples were immersed in distilled water until further preparation. All the specimens were cleaned with the help of periodontal scaler (Sonic flex 2000, Biberarch, Germany) and pumice slurry. These samples were then mounted in polyvinyl chloride pipes of (2.5 mm) radius with the help of acrylic resin (Malident, Heraeus, Kulzer/Hanau, Germany) up to cement-o-enamel junction (CEJ). Since, the surface treatment and bonding were to be carried on the buccal surface, these surfaces were polished with the help of carbide paper on a polishing machine (Automet,250Pro, Buheler, Germany) of 250 rpm along with water irrigation for 10 s. Not at any stage during the investigation the samples were allowed to dehydrate.

The samples were now arbitrarily assigned into six groups (n = 15 each) based on enamel surface treatment. Group 1 and group 2 surface conditioned with total etch + rinse. Group 3 and group 4 surface treated with Er,Cr:YSGG. Group 5 and group 6 surface conditioned with SEP. The surface treatment protocols for these groups were as follows:

Group 1 and 2 (Control): The surface of enamel etched using 37% phosphoric acid (Total Etch, Ivoclar, Vivadent, Schaan, Liechtenstein) for 30 s washed with water spray for 15 s and air dried until chalky white appearance. A single layer of Transbond XT primer (3 M Unitek, Monrovia, Calif) was adhered on the etched enamel and air dried for 5 s.

Group 3 and 4: Specimens were subjected to Er,Cr:YSGG phototherapy (Biolase-Waterlase I-Plus) with frequency 30 Hz and power 4.5 W in a circular non-contact position for a duration of 30 s each using tip size MZ8. The distance between tip and enamel surface was standardized at 2 mm [22]. A single layer of Transbond XT primer (3 M Unitek, Monrovia, Calif) was adhered on the etched enamel and air dried for 5 s.

Group 5 and 6: Samples were conditioned with Tansbond plus SEP (3 M Unitek, Monrovia, Calif) based on a lollipop system consisting of two compartments. In order to activate the product both compartments are squeezed together to form a single paste. The resultant paste is polished over the enamel surface for 15 s and air dried.

Now based on the type of bracket bonded to enamel surface. Group 1, 3 and 5 were bonded to metallic brackets (MB) (Roth 022, Ovation, GAC International, Inc.) with an average base surface of 12 mm<sup>2</sup> using

Transbond XT adhesive paste light cured (Astralis 7, Vivadent, Ivoclar) with an intensity of 400 mw/cm<sup>2</sup> for 20 s i.e., (10 s each in mesial and distal direction). Similarly, group 2,4,6 were bonded to ceramic bracket (CB) (Roth 022, Allure III, GAC International, Inc.) on the buccal surface of maxillary premolars having average base surface area of 12.2mm<sup>2</sup> using Transbond XT adhesive paste. The samples were light cured for 40 s i.e., (10 s each in mesial, distal, occlusal and gingival) direction using the same light source for metallic brackets.

A single operator did all the bonding procedure to avoid inter-operator disparity. Before shear bond strength (SBS) testing all specimen were placed in artificial saliva (Caphosol, NeutraSal) for 24 h at room temperature and underwent thermocycling (Applied Biosystems, Automated thermal cycler (ATC), CA, USA) i.e., accelerated aging to simulate oral condition between 10C to 55C with a dwell time of 30 s for 6000 cycles.

### 2.1. SBS testing

All samples from each group were positioned in a universal testing machine (Instron 8500 Plus, Canton) for SBS testing. The specimen was subjected to increasing load at the intersection of the tooth and bracket interface, at cross head speed of 0.5 mm/min in an occlusal gingival direction. The machine was connected to the computer which recorded the force to de-bond bracket in Newtons (N). Whereas, SBS values were calculated in megapascals (MPa) by dividing the force in N to bracket surface area in mm<sup>2</sup>

### 2.2. Adhesive Remnant Index (ARI)

After debonding the bracket, a stereomicroscope (Olympus, SZx9, Humburg, Germany) at magnification 60x was used to discover the sites of bond failure using ARI by Artun and Bergland [22]. The ARI consisted of the following interpretations.

- 0 = No adhesive was found to be on the tooth.
- 1 = Less than half of the adhesive found to be on tooth surface
- 2 = More than half of the adhesive found on the tooth surface
- 3 = All the adhesive found on tooth.

The data obtained from SBS testing demonstrated normal distribution in accordance to the Kolmogorov-Smirnov test. All the data acquired by SBS testing was tabulated using statistical programme of social sciences (SPSS version 21, Inc., Chicago, US). The mean SBS of six groups were equated by analysis of variance (ANOVA) and pairwise comparison between groups were analysed with the Post hoc Tukey test keeping a significance level of ( $p < 0.05$ )

## 3. Results

Table 1 demonstrates mean SBS values and standard deviation (SD) of all six experimental groups.

The maximum SBS values were displayed by group 1 total etch + rinse MB (14.84 ± 1.78) whereas the minimum shear bond strength values were exhibited by group 6 SEP CB (9.99 ± 0.91). Samples treated with total etch + rinse MB (14.84 ± 1.78) and group 3 Er,Cr:YSGG (MB) unveiled comparable bond strength ( $p > 0.05$ ). Similarly, experimental group 2 total etch + rinse CB (12.52 ± 1.28) was found to be comparable to group 4 Er,Cr:YSGG CB (12.14 ± 4.12) ( $p > 0.05$ ). Moreover, bond strength scores among group 5 SEP MB (10.46 ± 0.55) and group 6 SEP CB (9.99 ± 0.91) were also comparable ( $p > 0.05$ ). For SBS values, analysis of variance (ANOVA) presented significant difference among the experimental groups ( $p < 0.001$ ).

Failure modes based on the ARI is demonstrated in Table 2. In experimental group 1 total etch + rinse MB, group 2 total etch + rinse CB group 5 SEP MB and group 6 SEP CB pertinent form of failure was adhesive. Similarly, in group 3 Er,Cr:YSGG MB and group 4 Er,Cr:YSGG CB common type of failure exhibited was admixed. Whereas, cohesive

**Table 1**  
Means and SD for bond strength values among experimental groups using ANOVA and Tukey multiple comparisons test.

Surface conditioning/ Type of bracket bonded	Mean (MPa)	SD (MPa)	P value <sup>†</sup>
Group 1: Total etch + rinse MB <sup>†</sup> (Control)	<b>14.84</b>	1.78	< 0.001
Group 2: Total etch + rinse CB <sup>†</sup> (Control)	12.52	1.28	
Group 3: Er,Cr:YSGG MB <sup>†</sup>	13.96	4.88	
Group 4: Er,Cr:YSGG CB <sup>†</sup>	12.14	4.12	
Group 5: Self-Etching Primer (SEP) MB <sup>†</sup>	10.46	0.55	
Group 6: Self-Etching Primer (SEP) CB <sup>†</sup>	<b>9.99</b>	0.91	

MB: Metallic Bracket, CB: Ceramic Bracket.

The highest and lowest shear bond strength values are in bold.

<sup>†</sup> Significantly different from groups- Total etch + rinse CB, Er,Cr:YSGG CB, Self-Etching Primer MB, Self-Etching Primer CB (p < 0.05).

\* Significantly different from groups- Total etch + rinse MB, Er,Cr:YSGG MB, Self-Etching Primer MB, Self-Etching Primer (SEP) CB (p < 0.05).

<sup>†</sup> Significantly different from groups- Total etch + rinse MB, Total etch + rinse CB, Er,Cr:YSGG MB, Er,Cr:YSGG CB (Tukey multiple comparison test).

<sup>†</sup> Showing significant difference among study group (ANOVA).

**Table 2**  
Modes of failure in percentages among experimental groups using Adhesive Remnant Index (ARI).

Experimental Groups	0	1	2	3	n
Group 1: Total etch + rinse MB (Control)	5%	5%	40%	50%	10
Group 2: Total etch + rinse CB (Control)	28%	20%	25%	32%	10
Group 3: Er,Cr:YSGG MB	25%	30%	20%	25%	10
Group 4: Er,Cr:YSGG CB	30%	20%	30%	20%	10
Group 5: Self-Etching Primer (SEP) MB	40%	30%	15%	15%	10
Group 6: Self-Etching Primer (SEP) CB	50%	25%	10%	15%	10

MB: Metallic Bracket, CB: Ceramic Bracket.

failure was demonstrated in group 2 total etch + rinse CB.

#### 4. Discussion

In the current study enamel surface was conditioned by using various surface treatment and bonded to two different brackets i.e., ceramic and metallic across unlike experimental groups. The bonding efficacy of trial groups was estimated by shear bond strength testing. Whereas, failure pattern among groups was evaluated using ARI. The present study, was constructed on the hypothesis that enamel surface treated with phototherapy Er,Cr:YSGG and bonded to different bracket prototypes will present comparable bond strength to conventional (etch and rinse). Surprisingly, the hypothesis was accepted as SBS values among samples treated with Er,Cr:YSGG and total (etch and rinse) were found to be comparable when bonded to dissimilar brackets.

Direct bonding technique has revolutionized, advanced and anticipated the clinical outcome of orthodontic treatment. However, there is a need to enhance the procedure of bonding by cutting cost and saving time [23,14]. Due to different brands of adhesive and primers available in the market there selection according to clinical scenario is still an issue for the orthodontist [23]. Primary choice of these primers and adhesive is dependent on efficiency, cost benefit analysis and technique safety [24].

In the present study, enamel conditioned with conventional (etch and rinse) Transbond XT displayed higher SBS values ( $14.84 \pm 1.78$ ) ( $12.52 \pm 1.28$ ) compared to enamel surface treated with Transbond Plus SEP ( $10.46 \pm 0.55$ ) ( $9.99 \pm 0.91$ ) in both bracket types i.e., metallic and ceramic. The findings of the current study were in concurrence with the studies by Bishara et al. [25] Yamada et al. [26] Grubisa et al. [27] Arsh et al. [28]. However, there are studies by Behnam et al. [14] Velo et al. [29] which postulate that use of SEP as surface conditioner on enamel presents better bond strength. These

discrepancies in results can be attributed to types of adhesives used, type of debonding technique, storage condition, study design in-vivo or in-vitro, type of teeth (animal vs human) and bonding surface [30]. Nevertheless, in authors opinion better bond strength in conventional (etch and rinse) can be accredited to the use of 37% phosphoric acid on enamel surface producing uniform deep resin tags whereas shallower pattern on enamel surface by SEP can be a reason of low bond strength among this group. Evidence advocates a bond strength of 8Mpa is acceptable for bonding bracket [31]. In the current study, experimental group surface conditioned with Transbond Plus SEP displayed lowest bond strength scores of ( $9.99 \pm 0.91$ ). Interestingly, these bond strength values were found to be greater than the acceptable limits.

Alternatively, in the existing study Er,Cr:YSGG phototherapy lased enamel surface unveiled comparable bond strength to traditional (etch and rinse). Er,Cr:YSGG belonging to erbium family has bactericidal property, precise cutting of dental hard tissues and painless etching of enamel and dentine [32]. The laser is convenient to use and saves time when compared to conventional method of acid etching as there is no washing of surface which decreases total etching time [32,33]. Moreover, phosphoric acid used in conventional method of (etch and rinse) is more aggressive on the enamel surface and results in chemical change i.e. decalcify the inorganic matter and modifies the organic matter [34]. Phototherapy of enamel surface by Er,Cr:YSGG produces caries free demineralized surface more resistant to acid attack caused by plaque. This is an advantage for patients undergoing ortho treatment [34,32]. A contradicting evidence exists in the literature regarding use of phototherapy for the surface treatment on enamel [35–37]. In authors opinion disparity among studies can be due to different laser parameters frequency and power, distance from the surface, duration of laser, irrigation and type of laser tip used [38,39].

Intriguingly, in the current study according to ARI mode of failure of surface etched with Er,Cr:YSGG phototherapy demonstrated admixed type of failure pattern. Apparently, there are no studies to generalize the conclusions of the present study. But in authors opinion due to quality of material, debonding protocol and lateral forces can be a reason for admixed failure pattern in laser etched surface. Similarly, samples etched with SEP in group 5 and 6 presenting a gentler etch pattern most of the failures was adhesive. These findings were in correlation with low SBS scores. Whereas, the highest ARI scores was found in group 1 and group 2 these findings were in conjecture with study by Sharma et al. [12] and Behnam et al. [14].

The contemporary study has limitations based on its in-vitro design. The conclusions of the existing study are pertinent to the type of laser (4.5 W and 30 Hz), type of primers, adhesives and brackets. Microscopic sections of debonded brackets and tooth surface needs to be investigated under scanning electron microscope (SEM). The results should be reevaluated in vivo conditions.

#### 5. Conclusion

Enamel etched for bonding bracket with Er,Cr:YSGG phototherapy at (4.5 W and 30 Hz) displayed comparable bond strength to conventional Transbond XT independent on the type of brackets used.

#### Conflict of interest

The author declares no conflict of Interest.

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