

Effect of Laser Conditioning and Different Adhesive Strategies on Bond Strength of a Bulk Fill and a Microhybrid Resin Composite

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Abstract Purpose: To evaluate the effect of laser conditioning and adhesive strategies on bond strength of a bulk fill and a microhybrid resin composite. **Methods:** 96 human posterior teeth's buccal and lingual surfaces were ground flat to expose dentin surfaces with standard smear layer (N=192). The specimens were divided into 16 experimental groups according to (1) Laser-conditioning (Laser-etched group/control group); (2) Adhesive strategies (etch&rinse, Adper Single Bond2(SB2), two step self-etch ClearfilSE Bond(CSE), multi-mode adhesive All-Bond Universal with self-etching technique(ABU-SE), or etch&rinse technique(ABU-ER); (3) Restorative materials (Z250/SDR). All the restorative applications were applied according to the manufacturer's directions. The specimens were stored in 100% humidity for 24 hours. The specimens were placed on a shear bond test machine at a crosshead speed of 1 mm/min. The values were recorded at the time of failure of composite resins. The bond strength values for shear forces were reported in MPa and derived by dividing the imposed force at the time of fracture by the bonded area. The failed samples were examined under a stereomicroscope at X20 magnification to determine the mode of failure. The data were statistically analyzed with three-way ANOVA and multiple comparisons were made by Bon Ferroni test at 5% significance level ($p<0.05$). **Results:** SDR and Z250 yielded statistically significant difference when bonded with ABU-ER without laser conditioning ($p=0.008$). The predominant mode of failure was mixed type. **Conclusion:** Laser conditioning did not affect shear bond strength values of a bulk fill and a microhybrid resin composites regardless of adhesive system.

Keywords: bond strength, adhesive systems, laser, bulk fill resin composites

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1. Introduction

The search for faster and easier restorative procedures while maintaining adhesive efficiency and adequate bond strength is the backbone of progressive dental technologies. Recently the manufacturers have introduced the bulk fill resin composites which can be placed in bulks ranging from 4 to 6mm, instead of the conventional 2 mm incremental technique [1]. Placement of bulk fill resin composites involve less application steps by reducing the time-consuming total number of layers and polymerization period compared to the conventional resin composites.

Contemporary dental adhesives focus on providing effective bond strength values to different dental substrates. [2] Manufacturers developed various adhesive systems, regarding different adhesive strategy and application steps. These adhesive systems offer the clinician the opportunity to consider which adhesive strategy could be used: They

are intended to "all-in-one" one-step self-etch adhesive concept and known as "multi-mode" or "universal" adhesive systems [3,4,5,6].

In recent years, many types of laser systems can be used for dental applications like dentin/enamel conditioning or cavity preparation, due to their ability to efficiently remove dental tissues [7,8,9]. Successful removal of dental hard tissues while minimizing thermal damage risk and avoiding smear layer formation may be accomplished by a recently developed hydrokinetic laser named Er, Cr: YSGG laser [10]. Surface pretreatment is one of the particular benefits of Er,Cr:YSGG laser. Er,Cr:YSGG laser treatment is found to be an effective substitute for conventional acid-etching on enamel [11,12]. However, for dentin, some studies [9,13] demonstrated lower bond strengths with diamond bur application compared to the Er,Cr:YSGG laser ablated collagen fibers. Therefore, several studies have concentrated on laser ablation on enamel and dentin conditioning and reported that there were some micro porosities on tooth structures with absence of smear layer [14-20].

The bond strength is one of the major important factors that determine the success and longevity of the resin based restorations [21,22,23,24]. However, dental literature is limited about the effect of laser conditioning on the bond strength of multimode adhesive systems and bulk fill resin composites.

The purpose of this in vitro study was to evaluate the effect of laser conditioning and different adhesive strategies on the bond strength of bulk fill resin composites to dentin. The null hypothesis tested was bond strength values are not affected by laser-conditioning regardless of adhesive system and resin composite types.

2. Materials and Methods

This study was supported by Başkent University Research Fund and approved by Başkent University Institutional Review Board (Project no: D-KA 16/04). 96 caries free and intact, anonymized human molars were used for the study. All teeth were embedded in self-curing acrylic resin, then, buccal and lingual surfaces were ground flat to expose dentin surfaces and polished with 600-grit silicone carbide paper under running water to obtain standard smear layer (N=192). The specimens were randomly divided into 16 experimental groups according to (1) Laser irradiation

(Laser irradiated group/control group); (2) Adhesive strategies (etch&rinse, Adper Single Bond 2 (SB2), two-step self-etch Clearfil SE Bond (CSE), multi-mode adhesive All-Bond Universal with self-etching technique (ABU-SE), or etch&rinse technique (ABU-ER); (3) Restorative materials (Filtek Z250/Surefil SDR Flow) (n=12) (Table 1).

Table 1. Test Groups

Group 1	All Bond Universal (Self Etch)[ABU SE]+ Filtek Z250
Group 2	All Bond Universal (Etch&Rinse)[ABU ER] + Filtek Z250
Group 3	Adper Single Bond 2[SB2] + Filtek Z250
Group 4	Clearfil SE Bond[CSE]+ Filtek Z250
Group 5	All Bond Universal (Self Etch)[ABU SE]+ SDR
Group 6	All Bond Universal (Etch&Rinse)[ABU ER] + SDR
Group 7	Adper Single Bond 2[SB2] + SDR
Group 8	Clearfil SE Bond[CSE]+ SDR
Group 9	Laser+ All Bond Universal (Self Etch)[ABU SE]+ Filtek Z250
Group 10	Laser+ All Bond Universal (Etch&Rinse)[ABU ER] + Filtek Z250
Group 11	Laser+ Adper Single Bond 2[SB2] + Filtek Z250
Group 12	Laser+ Clearfil SE Bond[CSE]+ Filtek Z250
Group 13	Laser+ All Bond Universal (Self Etch)[ABU SE]+ SDR
Group 14	Laser+ All Bond Universal (Etch&Rinse) [ABU ER]+ SDR
Group 15	Laser+ Adper Single Bond 2[SB2] + SDR
Group 16	Laser+ Clearfil SE Bond[CSE]+ SDR

Table 2. Materials used in the study

Material	Type	Composition	Protocol for use	Manufacturer
Clearfil SE Bond	Self-Etch Adhesive System	PRIMER: HEMA (%25-45), MDP, Hydrophilic aliphatic dimethacrylate, Water, Initiators, Accelerators, Dyes BOND: BIS-GMA (%25-45), HEMA (%20-40), sodium fluoride <1%, MDP, Hydrophobic aliphatic dimethacrylate, Silanated Colloidal silica, dl-Camphorquinone, Initiators, Accelerators	-Apply primer actively for 20 s. -Apply light jet of air for 5 s. -Apply bond -Light activation for 10 s.	Kuraray, Okayama, Japan
All Bond Universal	Universal Adhesive System	10-MDP, 2-HEMA, Bis-GMA, ethanol, water, photoinitiators	Self-Etching Technique: 1. Apply two separate coats of adhesive, scrubbing the preparation with a microbrush for 10-15 seconds per coat. Do not light cure between coats. 2. Evaporate excess solvent by thoroughly air-drying at least 10 seconds. 3. Light cure for 10 seconds. Total-Etching Technique: -Etch enamel and dentin using an etchant for 15 seconds. -Rinse thoroughly. Remove excess water by blotting the surface with an absorbent pellet, -Apply steps 1, 2, and 3 as above.	Bisco, IL, USA
Adper Single Bond 2	Etch & Rinse Adhesive System	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acids 10% w/w 5nm diameter silica filler	-Apply etchant to enamel and dentin for 15 s. -Rinse for 10 s. -Blot excess water using a cotton pellet, do not air dry -Immediately after blotting, apply 2-3 consecutive coats of adhesive for 15 seconds with gentle agitation using a fully saturated applicator. -Gently air thin for 5 seconds to evaporate solvent -Light-cure for 10 seconds.	3M, ESPE, Seefeld, Germany
Surefil SDR Flow	Bulkfill Resin Composite	SDR patented UDMA, TEGDMA, EBPDMA, barium and strontium aluminofluoro-silicate glass (68 wt%/45 vol%)		Dentsply, Kostanz, Germany
Filtek Z250	Microhybrid Resin Composite	TEGDMA UDMA, Bis-EMA 60% by volume (without silane treatment) 0.01µm to 3.5µm with an average particle size of 0.6µm zirconia/silica		3M, ESPE, Seefeld, Germany

BIS-GMA: bisphenol A diglycidylmethacrylate ; HEMA: 2-hydroxyethyl methacrylate; MDP: 10-Methacryloyloxydecyl dihydrogen phosphate; UDMA: urethane dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate, Bis-EMA: Bisphenol A polyethylene glycol diether dimethacrylate; EBPDMA: ethoxylated Bis-GMA.

Dentin surfaces were irradiated with Er,Cr:YSGG laser (Waterlase MD, Biolase Technology Inc., CA, USA) with a power of 1 W at a wavelength of 2780 nm and a 20 Hz frequency with a pulse duration of 140 μs under 55% of water and %65 of air cooling. Laser was used in focused mode and the focal distance of the sapphire tip (MZ6, 600 μm in diameter) was 1-2 mm.

All restorative materials were applied according to the manufacturer’s instructions (Table 2).

Following application of the adhesive, a plastic tube (3 mm in diameter and 4 mm in length) was placed on the dentin surface and filled with Filtek Z250 in two consecutive increments of 2 mm and in one 4 mm increment for Surefil SDR Flow, followed by polymerizing each increment with a LED curing device (1000 mW/cm; LEDMAX 550, Benlioglu Dental, Ankara, Turkey) for 20 seconds. The specimens were stored in 100% humidity at 37°C for 24 hours before shear bond strength test measurements.

The specimens were placed on a Universal Testing Machine (Lloyd-LRX; Lloyd Instruments, Fareham, UK) and loaded at a cross-head speed of 1 mm/min. The values

were recorded at the time of failure of composite resins. The shear bond strength values were calculated in MPa by dividing the shear load (Newton) at the time of fracture by the bonded area (mm²). The failure modes were evaluated by a stereomicroscope at X20 magnification as adhesive, cohesive or mixed failures.

The results were analyzed using the statistical package Statistical Package for the Social Sciences (SPSS) 14.0.0 for Windows (SPSS Inc., Chicago, IL, USA). The data were statistically evaluated by three-way ANOVA and multiple comparisons were made using Bonferroni test at a significance level 0.05. (p<0.05)

3. Results

The mean shear bond strength values, standard deviations and p values are shown in Table 3. No statistically significant difference was found between the groups evaluated (p>0.05). There was only a statistically significant difference between Surefil SDR and Filtek Z250 groups, bonded with ABU-ER without laser conditioning (p=0.008).

Table 3. Mean, standard deviations and p values of the groups tested

GROUPS		ABU SE	ABU ER	SB2	CSE	P values
Without Laser Conditioning	Z250	22,37±9,75	24,14±13,27	15,87±5,15	20,44±9,88	0,086
	SDR	21,08±8,24	15,12±7,53	20,41±7,72	22,92±8,81	0,120
	P values	0,702	0,008*	0,180	0,463	
With Laser Conditioning	Z250	19,69±9,62	19,42±5,44	17,76±6,4	14,18±8,91	0,338
	SDR	21,55±6,15	20,56±6,32	14,85±5,35	17,21±9,14	0,174
	P values	0,582	0,736	0,388	0,370	
With vs Without Laser Conditioning	Z250					
	P values	0,427	0,163	0,576	0,065	
	SDR					
	P values	0,890	0,109	0,100	0,092	

*Indicates statistically significant difference(p<0.05).

ABU SE: All Bond Universal (self-etch); ABU ER: All Bond Universal (etch&rinse); SB2: Adper Single Bond2; CSE: Clearfil SE Bond

The frequencies of failure mode for all groups are shown in Figure 1. Analysis of bond failure showed a greater incidence of mixed failures for all groups.

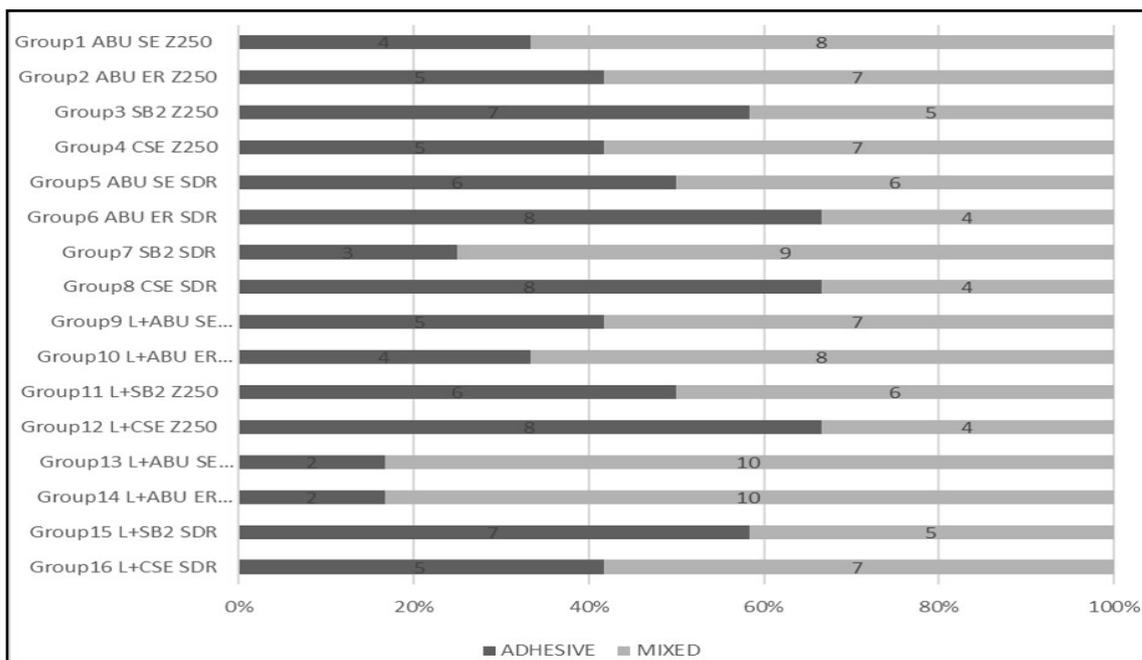


Figure 1. Failure modes of the groups tested. ABU SE: All Bond Universal (self-etch); ABU ER: All Bond Universal (etch&rinse); SB2: Adper Single Bond2; CSE: Clearfil SE Bond; L: Laser

4. Discussion

The results of the present study demonstrated no statistically significant difference between the shear bond strength values of groups with or without laser conditioning regardless of adhesive system and resin composite type used, thus the null hypothesis was accepted. The dental literature contains contradictory results about the use of lasers for dentin conditioning. Ramos et al. reported lower micro-tensile bond strength values on laser-treated dentin surfaces [25]. Ansari et al. [9] compared the micro-shear bond strength of resin composite, after bur or laser and acid or laser conditioning. The results demonstrated that additional etching with phosphoric acid after Er,Cr:YSGG laser pretreatment may be necessary to improve the bond strength. On the other hand, in an in-vitro study by Chou et al., the bond strength of the laser-irradiated groups and the acid-etched groups yielded similar results on dentin [26].

According to Bachmann et al., laser irradiation might alter the structure and form of the organic matrix leading to obstruction of the adhesive penetration and expedition collagen degradation [27]. Although laser irradiated dentin surfaces exhibit an etching pattern, additional micro fragment-like structures might impair the adhesion of resin composite materials [28]. The controversial results in the literature may be related to the employed materials and methods like the physical parameters of the laser, resin material types or application of additional acid etching after laser conditioning [9].

Several studies compared different output settings of erbium lasers in terms of bond strength [7,8,9]. Başaran et al. [29] reported that increasing laser output had led to increased SBS values. Besides, lower power laser irradiation does not produce adequate changes on the tooth surface [30]. Thus the output of the laser is of significant importance since adhesion of composite resin restorations has been affected by the laser irradiation [31,32].

According to the data collected in the present study, Surefil SDR exhibited similar bond strength values as the other conventional resin composite Filtek Z250. Ilie et al. [33] evaluated the shear bond strength of bulk fill resin composites. Their results showed that performance of bulk fill resin composites was comparable or better than the nanohybrid resin composites. Contrary to our findings, Surefil SDR showed significantly high bond strength values in their study. However, it is clinically obligatory to cover a micro/nano hybrid resin composite layer owing to the low mechanical properties of Surefil SDR and this additional procedure prolongs the application time [33].

In a previous study, the shear bond strength of bulk fill and nanohybrid resin composites were evaluated and no statistically significant difference was observed between the groups tested. This finding is aligned with the outcomes of our study. The authors of that study also concluded that this finding could be of potential benefit to the clinicians because restoring with bulk fill resin composites are simpler than conventional composites and can be applied more efficiently [34].

'Universal' dentin adhesive systems are recently introduced into the market; however, the indications of these systems are still under debate. All-Bond Universal contains small amount of water and ethanol as solvent and

the pH is approximately 3.2. Jang et al. reported that very hydrophobic character of All-Bond Universal might enhance its adhesive performance for both application modes. According to their results, Single Bond Plus has demonstrated lower bond strength values than Clearfil SE and All-Bond Universal [35]. In the present study, there was no significant difference between the bond strength values of adhesive systems used. Vermelho et al. [36] compared the multimode adhesives with the self-etch and etch&rinse systems and reported that those adhesives showed good bond strength performance as well as the control groups regarding dentin. They also reported that biphenyl dimethacrylate (BPDm) and 10-MDP in All-Bond Universal, as its functional monomers might be responsible for the similar bond strength values when compared to Clearfil SE Bond.

The SBS testing methodology may be considered as the limitation of the present study. This method had been in use for the last three decades [37,38]. Although, this methodology is less complex and simpler to use than the micro testing counterparts, the discriminative efficiency may not be conclusive [38]. However, the shear bond strength method has been frequently being used to characterize the mechanical properties of the materials.

5. Conclusion

Based on the results of the present study, it can be concluded that laser conditioning did not affect the bond strength values of different types of adhesive systems and resin composites used.

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Statement of Competing Interests

The authors have no competing interests

List of Abbreviations

SB2: Adper Single Bond2
 CSE Clearfil SE Bond
 ABU-SE: All-Bond Universal with self-etching technique
 ABU-ER: All-Bond Universal etch&rinse technique
 L: Laser

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