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Influence of diode laser and warm air drying on the shear bond strength of Lithium di-silicate to Dentin. An in-vitro study

Influência do laser de diodo e da secagem com ar quente na resistência ao cisalhamento do Di-silicato de Lítio a dentina. Um estudo in-vitro

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ABSTRACT

Objective: The current study aimed to evaluate the effect of diode laser irradiation (980 nm) and warm air drying (50°C) on shear bond strength between Lithium di-silicate (IPS e.max; Ivoclar) and human dentin using both (Etch & Rinse) adhesive, Adper™ Single Bond 2 (3M ESPE) and (Self-etch) adhesive, Single Bond Universal™ (3M ESPE) before adhesive polymerization. **Material and Methods**: 54 sound lower molars were sectioned to obtain flat dentinal surfaces. Specimens were divided into 2 equal groups (n=27): Group 1 (ER) and Group 2 (SE) according to bonding approach. Each subgroup was subdivided according to dentin surface treatment into 3 equal subgroups (n=9): Control (Co), Diode laser irradiation (L) and Warm air drying (W). All specimens were adhesively cemented to IPS e.max® CAD discs using RelyX™ Ultimate Clicker™(3M ESPE) resin cement. Samples were then subjected to pre-loading in a thermodynamic manner. All samples were tested for shear bond strength using computer-controlled material testing machine. Data analysis was performed using two-way (ANOVA) ($p < 0.05$) followed by pair-wise Tukey's post-hoc tests. **Results:** In (SE) group, the subgroup (W) had the highest shear bond strength values followed by (Co) subgroup and the least was (L) subgroup with statistically significant difference. As for (ER) group, the subgroup (W) had the highest shear bond strength values followed by (Co) subgroup and the least was (L) subgroup with no statistically significant difference. **Conclusion:** Warm air drying for (SE) bonding approach increased shear bond strength of Lithium di-silicate to human dentin and can be introduced as a new effective protocol.

KEYWORDS

Adhesives; Diode laser; IPS e.max; Shear bond strength; Warm air drying.

RESUMO

Objetivo: o objetivo do estudo atual é avaliar o efeito da radiação do laser de diodo (980nm) e secagem de ar quente (50°C) na resistência ao cisalhamento entre dissilicati de Lítio (IPS e.max; Ivoclar) e a dentina humana usando ambos modelos de adesivos (condicionamento total) Adper™ Single Bond e (auto-condicionante) Single Bond Universal™ (3M ESPE), Single Bond UniversalTM (3M ESPE) antes da fotopolimerização. **Material e Métodos:** 54 segundos molares inferiores foram selecionados para obter superfícies dentinárias planas. Os espécimes foram divididos em 2 grupos iguais (n=27): grupo 1 (ER) e grupo 2 (SE) de acordo com protocolo de adesividade. Cada grupo foi subdividido de acordo com o tratamento de superfície dentro de 3 subgrupos iguais (n=9): Controle (co), irradiação com laser de diodo (L) e secagem com ar quente (W). Todos os espécimes foram adesivamente cimentados a discos de IPS emax CAD usando RelyX Ultimate Clicker (3M ESPE) cimento resinoso. As amostras foram então submetidas a pré-carregamento de forma termodinâmica. Todas as amostras foram testadas para resistência a cisalhamento usando máquina de teste de materiais controlados por computador. A análise de dados foi realizada usando ANOVA dois fatores ($p<0.05$) seguindo por testes de Tukey pareado como test post-hoc. **Resultados:** No grupo (SE), o subgrupo (W) apresentou maiores valores de resistência ao cisalhamento seguindo o subgrupo (Co) é o menor foi o subgrupo (L) com diferença estatisticamente significativa. Já para o grupo (Er), o subgrupo (W) apresentou os maiores valores de resistência ao cisalhamento seguido do grupo (Co) e o menor foi o subgrupo (L) sem diferença estatisticamente significante. **Conclusão:** a secagem com ar quente para a abordagem de adesividade (Se) aumentou a resistência ao cisalhamento do dissilicato de lítio à dentina humana e poderia ser introduzido como um novo e eficaz protocolo.

PALAVRAS-CHAVE

Adesivo; Laser diodo; IPS e.max; Resistência ao cisalhamento; Secagem com ar quente.

INTRODUCTION

Adhesion of indirect restorations to dentin is considered a critical step which affects their longevity and success. The achievement of a strong reliable bond, will increase fracture resistance of both the tooth structure and the restoration [1,2]. In addition, the goal of adhesion is to prevent micro-leakage, marginal discoloration, secondary caries and postoperative sensitivity [3-5]. Dentinal bonding is achieved by hybridization, in which chemical ionic bonds between acid monomers of the adhesive system and calcium content of hydroxyapatite crystals takes place [2-4,6,7].

Micro-shear bond strength to dentin using (Self-etch) adhesive, Single Bond Universal™ was superior to (Etch & Rinse) adhesive, Adper™ Single Bond 2 but the bond strength decreases over time. The higher bond strength was attributed to chemical bonding with calcium in dentin [8]. There was no significant difference in bond strength values among various adhesives using both bonding approaches before adhesive cementation to dentin [7].

Etch & Rinse bonding approach still remains an acceptable option in clinical practice. Over drying of dentin will cause collapse of the collagen network, which prevents adhesive monomer diffusion and thus less efficient hybridization takes place [9,10]. While in case dentin is over wet, phase separation between hydrophilic and hydrophobic components of the adhesive takes place. This will lead to formation of voids and globules at the interface between adhesive and dentin and also incomplete monomer polymerization [11,12].

Single-step Self-Etch adhesives merge all the three bonding steps into a single application to the tooth surface before cementation of the restoration [4,9]. Their main problem is excessive hydrophilicity, therefore they attract water from dentin which is intrinsically moist [13]. It has been reported that these adhesives behave as semipermeable membranes after their polymerization; thus, water will diffuse from dentin into the adhesive layer which eventually deteriorates the bond strength [14-17].

For both bonding approaches, residual water and solvents should be eliminated from the demineralized dentin before polymerization. However, complete moisture removal is difficult to achieve and it depends on the properties of the solvent [15]. A clinical approach was introduced using warm air stream to evaporate solvents from the adhesive in order to achieve a more stable dentin bonding [18].

Shear bond strength of warm air-dried samples was significantly higher using different types of Self-Etch adhesives and it was attributed to the type of adhesive and the vapor pressure of solvent monomer [19]. Another in-vitro studies showed a significant increase in micro-tensile resin/dentin bond strength using Etch & Rinse adhesive [18,20]. It was explained that warm air stream evaporated the solvent before adhesive polymerization, which improved the bond strength [18].

Micro-tensile bond strength of both ethanol-based and acetone-based Etch & Rinse adhesives increased immediately and after 6 months period. Both adhesives showed higher values after warm air drying but ethanol-based adhesives showed significantly higher results. Authors claimed that, this increase was due to difference in vapor pressure and boiling points of the two solvents. Generally, higher values were achieved due to close contact of polymerized adhesive chains which prevented moisture accumulation [20].

Micro-tensile bond strength to dentin using water-based Etch & Rinse adhesive was significantly higher compared to ethanol and acetone-based adhesives, when they were subjected to warm air-drying at 60 C°. It was explained that, excessive moisture was completely eliminated from water-based adhesives due to the higher rate of water evaporation and its lower vapor pressure which increased the bond strength [21].

A recent approach was suggested to promote better adhesion to dentin using lasers. Gonçalves et al mentioned that Nd:YAG laser irradiation before adhesive polymerization, developed a substrate, in which adhesive and dentin fused together by the laser action [22]. This substrate increased shear and micro-tensile bond strength values of simplified dentin bonding systems (DBSs) [23-25]. It was explained that laser irradiation could possibly increase dentin bond strength by increasing penetration of DBSs into dentin [23].

Diode laser also can be an alternative to Nd:YAG and it has near-infrared irradiation, but it has more attractive usage and availability, such as lower size, weight, and cost [25-27]. Higher shear bond strength of resin/dentin bond after diode laser irradiation, using Self-Etch adhesives was observed [28,29]. It was suggested that laser irradiation before adhesive polymerization promoted its penetration in dentin and that higher bond strength values were related to the type of adhesive [28].

The adhesive readily infiltrated in dentin, was absorbed by (810 nm wavelength) diode laser and the resultant heat generation increased the degree of conversion of adhesive before adhesive polymerization as well [29]. An increase of micro-tensile bond strength of resin dentin bond was evident after diode laser irradiation (970 nm wavelength) using Etch & Rinse adhesives. It was attributed to the solvent evaporation and higher degree of conversion of the adhesive [25].

Also, higher micro-tensile bond strength values of Etch & Rinse adhesives were observed using (940 nm wavelength) diode laser. Authors clarified that, the reason was also solvent evaporation and the deeper adhesive penetration in dentin [30]. Likewise, micro-tensile bond strength of Self-Etch adhesives was significantly higher after (940 nm wavelength) diode laser irradiation. It was justified that diode laser created a local hot spot that induced adhesive transformation [31].

Accordingly, the rationale of this study was to evaluate the capability of diode laser irradiation and warm air drying to remove dentin moisture before adhesive application using both Etch & Rinse and Self-Etch approaches as an attempt to enhance shear bond strength between IPS e.max and dentin. The null hypothesis of this study was that diode laser and warm air had no effect on shear bond strength using both adhesive strategies.

MATERIALS AND METHODS

Sample size calculation

A sample size of (n= 9) in each group had 80% power to detect a difference between means of 4.94 with a significance level (alpha) of 0.05 (two-tailed) and 95% confidence interval. In 80% power of those experiments, the P value would be less than 0.05 (two-tailed) so the results would be deemed statistically significant. In the remaining 20% of the experiments, the difference between means would be deemed not statistically significant [25]. Graph-Pad InStat statistics software for Windows, Inc., La Jolla, CA, USA [32] was used for sample size calculation.

Sample preparation

Fifty-four freshly extracted human lower molars were collected from periodontially affected patients in the outpatient clinic of Oral Surgery Department of Faculty of Dental Medicine, Al-Azhar University after approval of ethical and scientific committees (602/3289). Anatomical crowns had both average buccolingual and mesiodistal dimensions (9 ± 1mm). Each crown was sectioned horizontally at the occlusal third, perpendicular to the long axis of the tooth and 1.5 mm below the buccal cusp tip to expose the dentinal surface using microtome sectioning device (Isomet 4000 precision cutting microsaw, Buehler, USA) [22,24].

Each dentin sample was immersed inside Self-cured polymethyl-methacrylate (PMMA) acrylic resin using custom-made cylindrical counter split die having dimensions (inner diameter 15 mm and height 20 mm) to create a resin mold. Exposed dentin surface was wet polished using 600 grit silicon carbide paper and placed on a polishing machine (EXAKT 400 CS, EXAKT Technologies, Oklahoma City, OK) for 60 seconds to standardize smear layer thickness [33].

Lithium di-silicate discs preparation

Fifty-four square-shaped IPS e.max discs having dimensions 5x5 mm^2 surface area and

2 mm thickness were sectioned from IPS e.max CAD blocks using the same microtome sectioning device. A digital caliber (INSIZE, China) was used to verify the dimensions of each disc. All surfaces of the discs were also wet polished using 400, 600, 800 and 1000 grit silicon carbide papers at 300 rpm using the same polishing machine as well [34].

The discs were then placed in the EP 3000 Press furnace (Ivoclar, Schaan, Liechtenstein) for 30 minutes until crystallization took place at temperature 850°C, according to IPS e.max manufacturer instructions. The bonding surface of each disc was etched using 5% Hydrofluoric acid (IPS® Ceramic Etching Gel, Ivoclar, Vivadent AG, Liechtenstein) for 20 seconds, air-dried and silanized using silane coupling agent (Monobond®Plus, Ivoclar, Vivadent AG, Liechtenstein.

Surface treatment and adhesion

Specimens were randomly divided into two equal groups (n=27), Etch & Rinse (ER) and Self-Etch (SE) according to the bonding approach to dentin. The two different adhesives which were used in this study and their manufacturer data are mentioned in Table I. In (ER) group, each dentin specimen was etched using 35% phosphoric acid etchant (3M Dental Products, St. Paul, MN, USA) for 15 seconds and surface moisture was blotted using a cotton pellet. Then two layers of Adper Single Bond 2 were applied. While in (SE) group, Single bond Universal self-etch adhesive was directly applied on each dentin specimen for 20 seconds. Both adhesives were applied according to manufacturer instructions.

Specimens were further subdivided into three equal subgroups (n=9) according to the type of surface treatment into Control (Co), warm air drying (W) and laser irradiation (L). In (Co) subgroup, dentin specimens were dried using oil-free compressed air for 5 seconds immediately after application of each adhesive. As for (W) subgroup, warm air drying of specimens was performed using warm air tooth dryer device (YS-AD-A, TDOU, China) instead of air drying for 10 seconds, 2 cm away from dentin surface at a temperature 50 C° and at constant air speed 30 Mph, Table II [19,20].

While in (L) subgroup, dentin specimens were subjected to 980 nm diode laser irradiation (Wiser, Doctor Smile, Italy) using 5 mm diameter bio-stimulation tip at a distance 1 mm away from dentin for 10 seconds instead of air drying [35]. The parameters of the diode laser were adjusted to (CW) continuous wave mode as shown in Table III [36]. Afterwards, in all (ER) group, each coat of adhesive was light cured for 10 seconds using LED unit 650 mW/ cm2 (LED-D, Woodpecker, Guilin, China). While in all (SE) group, a single coat of the adhesive was light cured for 20 seconds. The selected times were according to the adhesives' manufacturer instructions.

IPS e.max discs were adhesively cemented to dentin specimens using resin cement (Rely X Ultimate Clicker, 3M, ESPE, USA). The complex was placed under a specialized loading device which had static load of 5 kg. Each surface of the specimens was light cured for 20 seconds as per manufacturer instructions and then stored in distilled water until testing was performed.

Aging procedure

Specimens were mounted on a programmable logic-controlled equipment multimodal chewing simulator (ROBOTA, AD-TECH TECHNOLOGY CO., LTD., GERMANY), integrated with servo-motor (ACH-09075DC-T, AD-TECH TECHNOLOGY CO., LTD., GERMANY) at a temperature range between 5 °C and 55 °C. This simulator applies

Table I - The adhesives used and their manufacturing information

Fig.	Brand	Material	Composition	Manufacturer	Lot no.
1.	Adper™ Single Bond 2	Total-etch adhesive	10% colloidal Silica nanofiller (5 nm), BisGMA, HEMA, dimethacrylates, Ethanol, Water, a novel photoinitiator system (only 10 sec) curing time, methacrylate functional copolymer of polyacrylic, polyitaconic acids and Vitrebond polyalkenoic acid copolymer	3M ESPE, USA	51202
2.	3M™ Single Bond Universal Adhesive	Self-etch adhesive	MDP methacryloxydecyl phosphate monomer, Silane, BisGMA, HEMA, dimethacrylates, Ethanol, Water, a novel photoinitiator system (only 10 sec curing time), methacrylate functional copolymer of polyacrylic, polyitaconic acids and Vitrebond polyalkenoic acid copolymer	3M ESPE, AG, 41453 Neuss, Germany	41266

Table II - Technical data of warm air tooth dryer

Voltage	110 Volts
Wind speed	30 Mph
Temperature	Cold 50°C / Hot 90°C
Nozzle	Sterilizable
Dimensions	220×145×55mm
Weight	400 grams

Table III - Parameters of diode laser irradiation

Value	**Parameter**
980 nm	**Wave length**
10 seconds	**Time of dentin irradiation**
1 watt	**Average power**
Continuous wave	**Irradiation mode**
Bio-stimulation tip, 5 mm diameter	**Tip**

vertical and horizontal occlusal movements simultaneously in order mimic the thermodynamic conditions of oral cavity. 5 kg weight equivalent to 49.03 N chewing force was exerted on each specimen. The test was repeated 10000 times according to the previous studies [37,38].

Shear bond test

All specimens were mounted on Instron material testing machine (Industrial Products, Norwood, USA) with a loadcell of 5 kN. Data were recorded using Bluehill Lite software (Instron Instruments). Shear test was performed using compressive mode, in which a load was applied at the tooth-resin interface. This load consists of a mono-beveled chisel shaped metallic rod attached to the upper movable compartment of the testing machine traveling at cross-head speed of 0.5 mm/min.

The load required to de-bond each dentin specimen and Lithium di-silicate disc, was recorded and calculated in Megapascals (MPa). Custom-made metallic holding device was designed in order to support each specimen during shear bond testing. It consists of two parts, fixed base portion on which the acrylic resin block rests and upper movable portion. The movable portion is attached to the fixed base through two metallic rods, surrounded by a spring wire. This wire controls compressibility of both portions and is fixed by tightening screws.

Statistical analysis

Numerical data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Two-way Analysis of Variance (ANOVA) was performed to analyze the effect of dentin surface treatment and bonding approach on shear bond strength of dentin and IPS e.max. Tukey's post-hoc test was then used for pair-wise comparison of the significant ANOVA test data. Significance level was set at ($P \leq 0.05$) and statistical analysis was performed with the software Graph-Pad InStat statistics software for Windows, Inc., La Jolla, CA, USA [32]. Levene test for homogeneity of variance test revealed that equal variance was assumed hence Tukey's test was used for pair-wise comparisons.

RESULTS

Shear bond strength

As regards to SE group, two-way (ANOVA) revealed that (W) subgroup recorded the highest shear bond strength mean value followed by (Co) subgroup and (L) subgroup had the lowest mean value with statistically significant difference. While in (ER) group, subgroup (W) recorded the highest shear bond strength mean value followed by (Co) subgroup and (L) subgroup had the lowest mean value with no statistically significant difference. (SE) group recorded non significantly higher mean shear bond strength values than (ER) group. Results of two way (ANOVA) mean, standard deviation and confidence interval values are shown in Table IV and presented graphically in figure 1. In Table IV, the P-values in the last column on the right are concerned with comparison between bonding approaches within each surface treatment. The P-values in the last row indicate difference between surface treatments within each bonding approach. This P-value is for the overall comparison and not for pair-wise comparisons. It was statistically significant in SE bonding approach so pair-wise comparisons were done and represented by superscripts in the table.

Failure mode analysis

The observed modes of failure in (L) subgroup were predominantly mixed or/and adhesive with no cohesive failure. In (W) and (Co) subgroups, majority of samples showed mixed failures and few adhesive failures with no record of cohesive ones. Chi square test showed significant difference of failure mode distribution between the groups ($p=0.0005 < 0.5$) as shown in Table V.

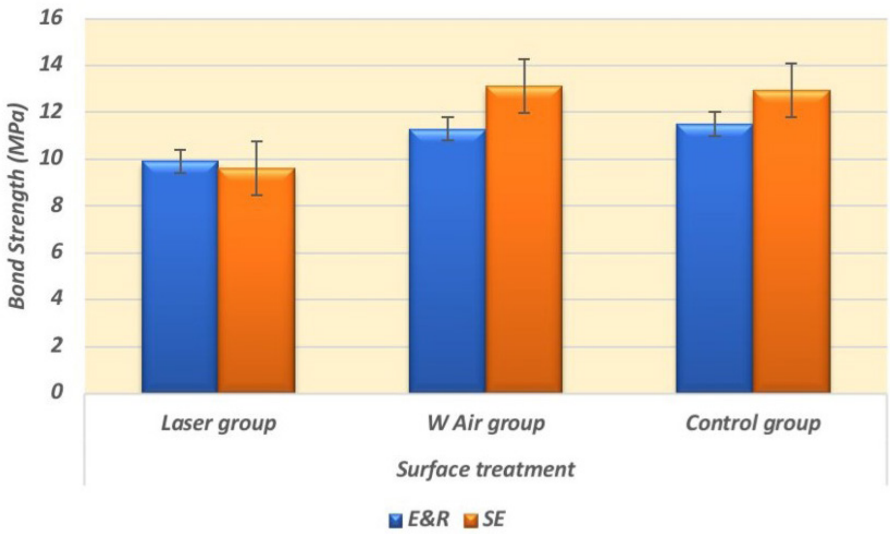

Figure 1 - Column chart showing the mean values of shear bond strength and standard deviation values in each group.

Table IV - Comparison of shear bond strength test Mean±Standard Deviation(SD) and confidence interval values in (Mpa) between different surface treatments using the two bonding approaches, where (ER) is Etch & rinse and (SE) is Self-Etch approach

Dentin surface treatment	Bonding approach						
	ER Mean±SD	95%CI Low	95%CI High	SE Mean±SD	95%CI Low	95%CI High	P value
Laser (L)	9.914±1.03	9.12	10.71	9.59^{B}±2.42	7.73	11.45	0.7165 ns
Warm air (W)	11.29±3.17	8.85	13.73	13.11^{A}±2.19	11.43	14.79	0.1756 ns
Control (Co)	11.5±3.03	9.17	13.83	12.94^{A}±0.96	12.2	13.68	0.1929 ns
p value	0.3877 ns			0.001*			

Significant ($p < 0.05$), CI; confidence intervals, Different superscript large letter in the same column indicates statistically significant difference.

Table V - Frequent distribution of failure mode analysis (%) of each group

Variables		Failure mode		
		Adhesive	Cohesive	Mixed
Surface treatment	Laser group	47.06%	0%	52.94%
	W Air group	21.05%	0%	78.95%
	Control group	36.84%	0%	63.16%
Chi square test	Chi value		15.12	
	p value		0.0005*	

*significant ($p < 0.05$).

DISCUSSION

Bonding to dentin has always been challenging to both clinicians and researchers. The adhesive should acquire complex chemistry in order to allow mixing of hydrophilic monomers, hydrophobic monomers, solvents and other additives [3]. There are still insufficient scientific data about ideal moisture elimination techniques from dentin, after adhesive application, in both in vivo and in vitro studies. Also, manufacturer instructions of using the adhesives, contain little information about the moisture condition of dentin surface.

Lithium di-silicate was the material of choice in this study, which is composed of lithium disilicate, that has diverse processing techniques. Lithium dislicate combines the advantages of having unique esthetic properties and superior mechanical properties after adhesive cementation [39]. Adhesive cement was used in this study which improves retention, fracture resistance and marginal adaptation of the restoration [3,4]. Therefore, this study aimed to achieve stronger adhesion between ceramic restoration and tooth structure, which is considered a critical issue for long term clinical success [3].

A specially designed tooth air dryer device was used in this study, that warmed up the infiltrated adhesive on the dentin surface of each specimen to 50°C temperature similar to several previous studies [18-21]. During function, restorations are usually exposed to thermal stresses, micro-leakage and water sorption. All specimens in this study were subjected to thermo-mechanical aging, before testing in order to simulate oral conditions. The number of thermal cycles was (10000 cycles), which was equivalent to one year of clinical service [40].

Laser interaction with tissues and its absorption rate is determined by its wavelength [41]. 980 nm wavelength was selected in this study, because it has higher absorption in water than other wavelengths found in the clinical office, and thus it would generate less heat during clinical application [42,43]. It was previously shown that, increase of pulpal temperature more than 5.5 °C would cause irreversible pulpitis [44].

Then, total power of 1 watt delivered to each specimen, was selected in this study to avoid occluding of the dentinal tubules and excessive heat generation as well [45,46]. Laser irradiation absorption would increase temperature of dentin, that leads to evaporation of both in organic and organic matrices and eventually carbonization of dentin [23]. Obliteration and collapse of dentinal tubules was evident using power 2 Watts and it increased using 4 Watts at 980 nm wavelength. It was explained that, the energy absorbed by dentin was higher and resulted in dentinal melting and recrystallization [47].

5 mm diameter bio-stimulation tip was used to ensure complete laser irradiation of dentin specimens [28]. The tip was 1 mm away from dentin surface, and laser was applied for only 10 seconds to avoid overheating and carbonization of dentin as well [35].

According to the two-way ANOVA, the null hypothesis was partially accepted, in which warm air drying resulted in significantly increased shear bond strength of (SE) group, while dentin laser irradiation (L) subgroup, had significantly the lowest shear bond strength values. In (ER) group, null hypothesis was accepted, since there was no significant difference among the three subgroups. Shear bond strength test was selected in this study, since it is the most frequent method to evaluate bonding of dental materials and can be easily compared with other studies [48].

Shear bond strength values were similar to an earlier study which obtained results between 10 and 50 MPa [49]. As for (SE) group, warm air drying had significantly increased shear bond strength in (W) subgroup as indicated by two-way ANOVA. This study agrees with several previous studies which reported that, the rise of adhesive temperature increases the kinetic energy of the molecules in the solvent (ethanol). This leads to solvent evaporation, which improves adhesive polymerization and bond strength [10,19,20].

Also, it was suggested that increase of adhesive temperature decreased the viscosity of the solvent and improved wettability of dentin surface [50,51]. According to the failure mode analysis, it was observed that (W) subgroup had the least adhesive failure. This could explain why this subgroup had the highest bond strength values in both groups [21].

Warm air drying didn't significantly increase micro-tensile bond strength of (ER) adhesive using (Adper Single Bond 2; 3M ESPE), which agrees with the results of this study [21]. It was justified that, the main drawback of HEMA hydrophilic monomer is water retention and formation of a hydrogel. Consequently, decrease of water vapor pressure occurs, which complicates moisture elimination even after warm air drying of the HEMA containing adhesives [18].

Shear bond strength values of (L) subgroup were the lowest, which agrees with previous studies [35,52]. Subgroup (L) had less values than subgroup (Co) in general which could be attributed to partial blockage of dentinal tubules [35]. Previous studies that reported increase of bond strength after laser irradiation, only recorded immediate bond strength and didn't consider thermomechanical aging of the specimens [22-25].

The (SE) group had slightly higher values than (ER) with no significant difference, which could be attributed to the presence of (MDP) and polyalkenoic acid copolymer in (SE) adhesive [8,53]. MDP contains carboxylate and/or phosphate monomers, which ionically bond to calcium in hydroxyapatite crystals to produce stable non-soluble Calcium salts that promote adhesion to the tooth structure [8,53-55]. It was reported that Self-Etch adhesion provided higher micro-tensile bond results than Etch & Rinse, using Single Bond Universal adhesive both immediately and after 6 months [55].

Polyalkenoic acid decreases water sorption and thus improve bond strength to dentin [8,52]. Mild dentin etching preserves hydroxyapatite in the hybrid layer which could act as a receptor for further chemical bonding. Also, collagen matrix would be supported and less liable to hydrolysis and thus bond deterioration [30]. The limitation of this study is that it isn't identical to the clinical situation, in which vital dentin has its own inherent moisture content [10,33]. Accordingly, further clinical research is highly recommended to obtain consistent outcome.

CONCLUSION

The following can be concluded, within limitations of this study

1. Warm air drying of SE adhesive before its polymerization improved shear bond strength of dentin to Lithium di-silicate IPS e.max discs;
2. Laser irradiation using the mentioned parameters and wavelength didn't enhance bond strength to dentin.

RECOMMENDATIONS

Warm air drying can be a useful tool to improve the shear bond strength between Lithium di-silicate indirect restorations (IPS. emax) and dentin. Further investigations using different laser wavelengths and parameters could enhance bond strength.

Author Contributions

MHMAR: conceived and designed the analysis, collected the data, wrote the paper. HIO: contributed data or analysis tools. HRM: performed the analysis.

Conflict of Interest

No conflicts of interest.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of: Faculty of Dental Medicine, Al-Azhar University after approval of ethical and scientific committees. The approval code for this study is (602/3289).

REFERENCES

1. Barutcigil K, Barutcigil Ç, Kul E, Özarslan MM, Buyukkaplan US. Effect of different surface treatments on bond strength of resin cement to a CAD/CAM restorative material. J Prosthodont. 2019;28(1):71-8. http://dx.doi.org/10.1111/jopr.12574. PMid:27880028.
2. Sofan E, Sofan A, Palaia G, Tenore G, Romeo U, Migliau G. Classification review of dental adhesive systems: from the IV generation to the universal type. Ann Stomatol (Roma). 2017;8(1):1-17. http://dx.doi.org/10.11138/ads/2017.8.1.001. PMid:28736601.
3. Van Landuyt KL, Snauwaert J, De Munck J, Peumans M, Yoshida Y, Poitevin A, et al. Systematic review of the chemical composition of contemporary dental adhesives. Biomaterials. 2007;28(26):3757-85. http://dx.doi.org/10.1016/j.biomaterials.2007.04.044. PMid:17543382.
4. Perdigão J, Reis A, Loguercio AD. Dentin adhesion and MMPs: a comprehensive review. J Esthet Restor Dent. 2013;25(4):219-41. http://dx.doi.org/10.1111/jerd.12016. PMid:23910180.
5. D'Arcangelo C, De Angelis F, Vadini M, D'Amario M, Caputi S. Fracture resistance and deflection of pulpless anterior teeth restored with composite or porcelain veneers. J Endod. 2010;36(1):153-6. http://dx.doi.org/10.1016/j.joen.2009.09.036. PMid:20003956.
6. Ferreira-Filho RC, Ely C, Amaral RC, Rodrigues JA, Roulet JF, Cassoni A, et al. Effect of different adhesive systems used for immediate dentin sealing on bond strength of a self-adhesive resin cement to dentin. Oper Dent. 2018;43(4):391-7. http://dx.doi.org/10.2341/17-023-L. PMid:29630484.
7. Albaladejo A, Osorio R, Toledano M, Ferrari M. Hybrid layers of etch-and-rinse versus self-etching adhesive systems. Med Oral Patol Oral Cir Bucal. 2010;15(1):e112-8. http://dx.doi.org/10.4317/medoral.15.e112. PMid:19767690.
8. Schoenhals GD, Berft CL, Naufel FS, Schmitt VL, Chaves LP. Bond strength assessment of a universal adhesive system in etch-and-rinse and self-etch modes. Rev Odontol UNESP. 2019;48. http://dx.doi.org/10.1590/1807-2577.08319.
9. Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, et al. Buonocore Memorial Lecture. Adhesion to enamel and dentin: current status and future challenges. Oper Dent. 2003;28(3):215-35. PMid:12760693.
10. Reis A, Loguercio AD, Azevedo CL, de Carvalho RM, Singer JD, Grande RH. Moisture spectrum of demineralized dentin for adhesive systems with different solvent bases. J Adhes Dent. 2003;5(3):183-92. PMid:14621240.
11. Meerbeek BVAN, Landuyt KVAN, Munck JDE, Hashimoto M, Peumans M, Lambrechts P, et al. Technique-sensitivity of contemporary adhesives. Dent Mater J. 2005;24(1):1-3. http://dx.doi.org/10.4012/dmj.24.1. PMid:15881200.
12. Tay FR, Gwinnett JA, Wei SH. Micromorphological spectrum from overdrying to overwetting acid-conditioned dentin in water-free, acetone-based, single-bottle primer/adhesives.

Dent Mater. 1996;12(4):236-44. http://dx.doi.org/10.1016/S0109-5641(96)80029-7. PMid:9002841.

13. Tay FR, Pashley DH. Have dentin adhesives become too hydrophilic? J Can Dent Assoc. 2003;69(11):726-31. PMid:14653938.

14. Tay FR, Pashley DH, Suh B, Carvalho R, Miller M. Single-step, self-etch adhesives behave as permeable membranes after polymerization. Part I. Bond strength and morphologic evidence. Am J Dent. 2004;17(4):271-8. PMid:15478490.

15. Jacobsen T, Finger WJ, Kanehira M. Air-drying time of self-etching adhesives vs bonding efficacy. J Adhes Dent. 2006;8(6):387-92. PMid:17243596.

16. Van Landuyt KL, Snauwaert J, Peumans M, De Munck J, Lambrechts P, Van Meerbeek B. The role of HEMA in one-step self-etch adhesives. Dent Mater. 2008;24(10):1412-9. http://dx.doi.org/10.1016/j.dental.2008.02.018. PMid:18433860.

17. Hashimoto M, Ohno H, Sano H, Kaga M, Oguchi H. In vitro degradation of resin–dentin bonds analyzed by microtensile bond test, scanning and transmission electron microscopy. Biomaterials. 2003;24(21):3795-803. http://dx.doi.org/10.1016/S0142-9612(03)00262-X. PMid:12818552.

18. Klein-Junior CA, Zander-Grande C, Amaral R, Stanislawczuk R, Garcia EJ, Baumhardt-Neto R, et al. Evaporating solvents with a warm air-stream: effects on adhesive layer properties and resin–dentin bond strengths. J Dent. 2008;36(8):618-25. http://dx.doi.org/10.1016/j.jdent.2008.04.014. PMid:18550254.

19. Ogura Y, Shimizu Y, Shiratsuchi K, Tsujimoto A, Takamizawa T, Ando S, et al. Effect of warm air-drying on dentin bond strength of single-step self-etch adhesives. Dent Mater J. 2012;31(4):507-13. http://dx.doi.org/10.4012/dmj.2011-258. PMid:22864201.

20. Reis A, Klein-Junior CA, de Souza FC, Stanislawczuk R, Loguercio AD. The use of warm air stream for solvent evaporation: effects on the durability of resin-dentin bonds. Oper Dent. 2010;35(1):29-36. http://dx.doi.org/10.2341/08-065-L. PMid:20166408.

21. Marsiglio AA, Almeida JC, Hilgert LA, D'Alpino PH, Garcia FC. Bonding to dentin as a function of air-stream temperatures for solvent evaporation. Braz Oral Res. 2012;26(3):280-7. http://dx.doi.org/10.1590/S1806-83242012000300016. PMid:22641449.

22. Gonçalves SE, de Araujo MA, Damião A. Dentin bond strength: influence of laser irradiation, acid etching, and hypermineralization. J Clin Laser Med Surg. 1999;17(2):77-85. http://dx.doi.org/10.1089/clm.1999.17.77. PMid:11189979.

23. Franke M, Taylor AW, Lago A, Fredel MC. Influence of Nd: YAG laser irradiation on an adhesive restorative procedure. Oper Dent. 2006;31(5):604-9. http://dx.doi.org/10.2341/05-110. PMid:17024950.

24. Marimoto AK, Cunha LA, Yui KC, Huhtala MF, Barcellos DC, Prakki A, et al. Influence of Nd: YAG laser on the bond strength of self-etching and conventional adhesive systems to dental hard tissues. Oper Dent. 2013;38(4):447-55. http://dx.doi.org/10.2341/11-383-L. PMid:23215546.

25. Maenosono RM, Bim Jr O, Duarte MA, Palma-Dibb RG, Wang L, Ishikiriama SK. Diode laser irradiation increases microtensile bond strength of dentin. Brazilian oral research. 2015;29(1):1-5. http://dx.doi.org/10.1590/1807-3107BOR-2015.vol29.0004.

26. Barutcigil Ç, Barutcigil K, Yasa B, Arslan H, Akcay M. Build-Up of a Resin Composite Core in a Fiber-Reinforced Post by a 2.78 μm-Pulsed Laser Treatment. J Laser Micro Nanoeng. 2015;10(2):166-70. http://dx.doi.org/10.2961/jlmn.2015.02.0011.

27. Kursoglu P, Motro PF, Yurdaguven H. Shear bond strength of resin cement to an acid etched and a laser irradiated ceramic surface. J Adv Prosthodont. 2013;5(2):98-103. http://dx.doi.org/10.4047/jap.2013.5.2.98. PMid:23755333.

28. El-Hakim NM, Mokhtar A, Hamza T. Effect of diode laser irradiation of bonding agents before curing versus standard bonding protocol on the shear bond strength between resin cement and dentin. Braz Dent Sci. 2019;22(3):395-407. http://dx.doi.org/10.14295/bds.2019.v22i3.1796.

29. Ramachandruni N, Moinuddin K, Smitha R, Naga Maheshwari X, Harish Kumar TVS. Influence of diode laser on the bond strength of self-etching adhesive systems to human dentin: an in vitro study. Contemp Clin Dent. 2019;10(2):338-43. http://dx.doi.org/10.4103/ccd.ccd_589_18. PMid:32308300.

30. Kasraei S, Yarmohamadi E, Ranjbaran Jahromi P, Akbarzadeh M. Effect of 940nm diode laser irradiation on microtensile bond strength of an etch and rinse adhesive (Single Bond 2) to dentin. J Dent (Shiraz). 2019;20(1):30-6. http://dx.doi.org/10.30476/DENTJODS.2019.44560. PMid:30937334.

31. Resaei-Soufi L, Ghanadan K, Moghimbeigi A. The effects of Er:YAG, Nd:YAG, and Diode (940nm) Lasers irradiation on Microtensile bond strength of two steps self-etch adhesives. Laser Ther. 2019;28(2):131-7. http://dx.doi.org/10.5978/islsm.28_19-OR-10. PMid:32921912.

32. Graphpad [Internet]. San Diego, CA: Graphpad; 2021 [cited 2021 feb 5]. Available from: www.graphpad.com

33. Choi AN, Lee JH, Son S, Jung KH, Kwon YH, Park JK. Effect of dentin wetness on the bond strength of universal adhesives. Materials (Basel). 2017 Nov;10(11):1224. http://dx.doi.org/10.3390/ma10111224.

34. Lien W, Roberts HW, Platt JA, Vandewalle KS, Hill TJ, Chu TM. Microstructural evolution and physical behavior of a lithium disilicate glass–ceramic. Dent Mater. 2015;31(8):928-40. http://dx.doi.org/10.1016/j.dental.2015.05.003. PMid:26076831.

35. Malekipour M, Alizadeh F, Shirani F, Amini S. The effect of 808 nm diode laser irradiation on shear bond strength of composite bonded to dentin before and after bonding. J Dent Lasers. 2015;9(2):69. http://dx.doi.org/10.4103/0976-2868.158465.

36. Golbar N, Kasraei S, Afrasiabi A, Mostajir E, Mojahedi SM. Effect of diode laser (810 nm) irradiation on marginal microleakage of multi-mode adhesive resins in class V composite restorations. J Lasers Med Sci. 2019;10(4):275-82. http://dx.doi.org/10.15171/jlms.2019.45. PMid:31875119.

37. Ozyoney G, Yanikoğlu F, Tağtekin D, Ozyoney N, Oksüz M. Shear bond strength of composite resin cements to ceramics. Marmara Dent J. 2013;1(2):61-6. http://dx.doi.org/ 10.12990/MDJ.201317511.

38. Yassini E, Mirzaei M, Alimi A, Rahaeifard M. Investigation of the fatigue behavior of adhesive bonding of the lithium disilicate glass ceramic with three resin cements using rotating fatigue method. J Mech Behav Biomed Mater. 2016;61:62-9. http://dx.doi.org/10.1016/j.jmbbm.2016.01.013. PMid:26849028.

39. Höland W, Schweiger M, Frank M, Rheinberger V. A comparison of the microstructure and properties of the IPS Empress® 2 and the IPS Empress® glass-ceramics. J Biomed Mater Res. 2000;53(4):297-303. http://dx.doi.org/10.1002/1097-4636(2000)53:4<297::AID-JBM3>3.0.CO;2-G. PMid:10898870.

40. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent. 1999;27(2):89-99. http://dx.doi.org/10.1016/S0300-5712(98)00037-2. PMid:10071465.

41. Parker S. Verifiable CPD paper: laser-tissue interaction. Br Dent J. 2007;202(2):73-81. http://dx.doi.org/10.1038/bdj.2007.24. PMid:17255986.

42. Cheong WF, Prahl SA, Welch AJ. A review of the optical properties of biological tissues. IEEE J Quantum Electron. 1990;26(12):2166-85. http://dx.doi.org/10.1109/3.64354.

43. Tsai CL, Chen JC, Wang WJ. Absorption properties of soft tissue constituents in the 900-to 1340-nm region. In: Mantsch HH, Jackson M, editors. Infrared spectroscopy: new tool in medicine

(Vol. 3257, pp. 118-125). Bellingham: International Society for Optics and Photonics; 1998. http://dx.doi.org/10.1117/12.306077

44. Sulieman M, Addy M, Rees JS. Surface and intra-pulpal temperature rises during tooth bleaching: an in vitro study. Br Dent J. 2005;199(1):37-40, discussion 32. http://dx.doi.org/10.1038/sj.bdj.4812558. PMid:16003425.

45. Umana M, Heysselaer D, Tielemans M, Compere P, Zeinoun T, Nammour S. Dentinal tubules sealing by means of diode lasers (810 and 980 nm): a preliminary in vitro study. Photomed Laser Surg. 2013;31(7):307-14. http://dx.doi.org/10.1089/pho.2012.3443. PMid:23756100.

46. Wetter NU, Walverde D, Kato IT, Eduardo CP. Bleaching efficacy of whitening agents activated by xenon lamp and 960-nm diode radiation. Photomed Laser Surg. 2004;22(6):489-93. http://dx.doi.org/10.1089/pho.2004.22.489. PMid:15684748.

47. Liu Y, Gao J, Gao Y, Xu S, Zhan X, Wu B. In vitro study of dentin hypersensitivity treated by 980-nm diode laser. J Lasers Med Sci. 2013;4(3):111-9. PMid:25606318.

48. Hamouda IM, Shehata SH. Shear bond strength of ormocer-based restorative material using specific and nonspecific adhesive systems. Int Sch Res Notices. 2011;2011:376097. http://dx.doi.org/10.5402/2011/376097.

49. Sakaguchi Ronald L, Powers John M. Craig's Restorative Dental Materials. Craig's Restorative Dental Materials. 13th ed. Philadelphia, PA: Elsevier Inc; 2012. p. 327-47.

50. Garcia FC, Almeida JC, Osorio R, Carvalho RM, Toledano M. Influence of drying time and temperature on bond strength of contemporary adhesives to dentine. J Dent. 2009;37(4):315-20. http://dx.doi.org/10.1016/j.jdent.2008.12.007. PMid:19203818.

51. Loguercio AD, Salvalaggio D, Piva AE, Klein-Júnior CA, Accorinte ML, Meier MM, et al. Adhesive temperature: effects on adhesive properties and resin-dentin bond strength. Oper Dent. 2011;36(3):293-303. http://dx.doi.org/10.2341/10-218L. PMid:21851256.

52. Zabeu GS, Maenossono RM, Scarcella CR, Brianezzi LF, Palma-Dibb RG, Ishikiriama SK. Effect of diode laser irradiation on the bond strength of polymerized non-simplified adhesive systems after 12 months of water storage. J Appl Oral Sci. 2018;27:e20180126. http://dx.doi.org/10.1590/1678-7757-2018-0126. PMid:30540073.

53. Muñoz MA, Luque I, Hass V, Reis A, Loguercio AD, Bombarda NH. Immediate bonding properties of universal adhesives to dentine. J Dent. 2013;41(5):404-11. http://dx.doi.org/10.1016/j.jdent.2013.03.001. PMid:23499568.

54. De Munck J, Van Meerbeek B, Yoshida Y, Inoue S, Vargas M, Suzuki K, et al. Four-year water degradation of total-etch adhesives bonded to dentin. J Dent Res. 2003;82(2):136-40. http://dx.doi.org/10.1177/154405910308200212. PMid:12562888.

55. Cardoso GC, Nakanishi L, Isolan CP, Jardim PD, Moraes RR. Bond stability of universal adhesives applied to dentin using etch-and-rinse or self-etch strategies. Braz Dent J. 2019;30(5):467-75. http://dx.doi.org/10.1590/0103-6440201902578. PMid:31596331.

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