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Influence of artificial aging on the bonding effectiveness of eight adhesives in class V cavities

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Abstract
The aim of this study was to compare the microtensile bond strengths (µTBS) of current eight self-etch and total-etch adhesives in class V cavities and to evaluate the effects of artificial aging (thermal cycling and mechanical loading). Class V cavities were prepared on 64 extracted human molar teeth and were divided into eight groups according to the bonding system used; CSE, OSP, SB, SSE, PRL, FLB, SMP, and CPB. All cavities were restored with a composite resin (Clearfil Majesty Posterior). Following restorative procedures, the restored teeth of each adhesive group were allocated to two subgroups (n=4): specimens that would receive thermal cycling (5000 cycles, 5° to 55°C) and mechanical loading (60,000 cycles-50 N) and control (C) without thermal cycling and mechanical loading. After storage in distilled water for 24 hours, restorations were sectioned longitudinally and bucco-lingually to rectangular rods of 1 mm thickness from the cavity floor of restorations. All specimens were then subjected to µTBS (MPa). Fracture mode analysis was performed under Stereomicroscopy. After thermal and mechanical loading, the bond strengths of the tested adhesives remained almost the same compared to their control groups, except for FLB and SMP ($p<0.05$). It was observed that thermal and mechanical loading doesn't have adversely effect on dentin bond strength of most of total-etch and self-etch adhesive systems in class V cavities. The dentin bond strengths of many different adhesive systems didn't adversely affect by thermal and mechanical load cycling. However, results vary greatly with adhesive system type.

Keywords: Thermal and mechanical loading, bond strength, dentin adhesive

1. Introduction

Dentin adhesives have been widely used in clinical dentistry, and different versions and commercial brands are constantly being introduced, claiming advantages over their predecessors. These bonding systems have been simplified and improved in order to provide increased long-term strength and promote the durability and reliability of adhesive restorations [1]. The basic mechanism of adhesion to enamel and dentin is essentially an exchange process involving replacement of minerals removed from the hard dental tissue by resin monomers that upon setting become micro-mechanically interlocked in the created porosities [2]. Adhesive systems can be classified according to their bonding mechanism. They can either completely remove the smear layer or incorporate it into the hybrid layer. This is achieved by etch-and-rinse and self-etch systems, respectively. Etch-and-rinse adhesive systems are still considered the gold standard and can achieve immediate bond strengths similar to that of enamel. Self-etch adhesives have become popular between clinicians for two main reasons: the duration of the procedure is reduced and postoperative sensitivity is less frequent [3].

The evaluation of bonding durability is important, as the bond between the restorative material and tooth substrate has a significant impact on the clinical success of aesthetic restorations [4]. A clinical trial is the most effective method to assess the quality of these materials. However, considerable time and resources are needed for such trials, and confounding factors make it difficult to discriminate among commercial adhesives. On the other hand, adhesive systems change rapidly. Therefore, an easy and rapid means is necessary to estimate the clinical outcome of adhesives in a realistic manner. In order to simulate the situation inside the mouth, the artificial aging process are carried out in recently studies [5]. A widely used artificial aging methodology is thermo-cycling. The ISO TR 11450 standard (1994) indicates that a thermo-cycling regimen comprised of 500 cycles in water between 5 and 55 °C is an appropriate artificial aging test. A literature review concluded that 10,000 cycles corresponds approximately to 1 year of *in vivo* functioning, rendering 500 cycles, as proposed by the ISO standard, as being very minimal in mimicking long-term bonding effectiveness. The use of thermal cycling (TC) in dental restorations is frequently seen in laboratory studies in order to simulate changing intraoral temperature conditions [6, 7]. Thermal cycling induces stress between a tooth structure and a restorative material at the bonding interface.

In addition to thermal aging, mechanical loading may also affect resin adhesion to tooth structure. Again, to simulate this stress *in vitro*, it is important that one imposes stress similar to that occurring *in vivo* [8]. One possibility is to 'age' restored cavities in a chewing simulator and afterward measure the bonding effectiveness [1, 9]. Mechanical cycling (MC) has been studied due to its potential capability of simulating mastication [6, 7]. The application of occlusal MC could increase the vulnerability of the restoration-cavity wall interface, which is already stressed by the curing contraction [10].

The application of thermal and mechanical stresses is used in *in vitro* studies in order to simulate natural aging process of the restoration. It is difficult to compare studies since they employ different loads, number of cycles and cycle frequency. Many studies that evaluate microleakage have conflicting results regarding the effectiveness of both mechanical and thermal stresses [11, 12], but there were very limited bond strength studies with different bonding materials [1,6-8]. Therefore the aim of this study was to evaluate influence of thermal and mechanical loading on microtensile bond strength (µTBS) of eight different dentin adhesives in Class V cavities. The null hypothesis tested was that thermal and mechanical loading has adversely effect on the µTBS of the adhesives to dentin.

2. Materials and Methods

Sample Preparation

Following appropriate University Human Research Ethics Board approval and patients' consent, 64 caries-free recently extracted human molars (due to periodontal problem) were selected, cleaned of debris with curettes, stored in a 0.1% sodium azide saline solution and used within 6 months after extraction. All of the teeth had been extracted from patients 18 to 60 years of age. Class V cavities were prepared on buccal and lingual surfaces using a high speed #245 carbide bur (KG Sorensen, Germany) under constant water cooling. Cavity preparations with cervical margins in dentin were 3 mm high, 4 mm wide and 1, 5 mm deep toward the pulpal chamber. The burs were replaced after every five preparations. Cavities were randomly divided to eight distinct groups of eight teeth according to the adhesive system used (Table 1).

Eight different dentin adhesive systems were applied to the cavities according to manufacturer's recommendations. Clearfil Majesty Posterior composite resin (Kuraray Medical, Tokyo, Japan) was built up incrementally on bonded cavities to a high of 4 mm and each 2 mm resin layer was cured for 40 seconds using a halogen curing unit (Optilux 501, Kerr/Demetron, Danbury, CT, USA) with a light output exceeding 600 mW/cm^2. Composite resins were placed flood from the cavities in order to obtain a longer stick. After the restorative procedure, the specimens were stored in distilled water at 37°C for 24 hours. Following restorative procedures, the restored teeth of each adhesive group were allocated to two subgroups (n=4): specimens that would receive thermal and mechanical load cycling, and control without cycling

C: Control group (no thermal cycling or mechanical loading)

TM: Thermal cycling (5000 cycles, 5-55 °C) and mechanical loading (60.000 cycles/ load=50N) group.

Thermal cycling and mechanical loading

Four teeth from each group were subjected to 5000 cycles in a thermocycling apparatus with two baths at 5 ± 2 °C and 55 ± 2 °C each with a dwell time of 30 seconds and a transfer time of 5 seconds between each bath (Thermocycler, Willytec, Munich, Germany). The root surfaces of the teeth were covered with a 1-mm thick light polyether impression material (Impregum Penta DuoSoft; 3M ESPE, Seefeld, Germany) with a dispenser gun (3M ESPE), and the excess silicone material was removed with a scalpel blade to provide a flat surface 2 mm below the facial cementoenamel junction of each tooth. The teeth were then embedded in acrylic resin (GC Pattern Resin LS; GC, Alsip, IL, USA). The thin layer of silicone material simulated the periodontal ligament on the root surfaces of the teeth. Occlusal contact loading was simulated in an artificial oral environment sliding wear tester (Chewing Simulator; University of Selcuk, Research Laboratory Center, Konya, Turkey) [13].

Specimens were stored in artificial saliva in a simulator chamber at 37 °C in occlusal contact similar to physiological conditions. Four specimens of each material were tested in a pin-on-block design with a 0.3-0.8 mm radius with eccentric sliding of a spherical natural enamel antagonist (palatinal cusps of human maxillar molars, which were extracted and embedded in acrylic resin) under permanent contact with specimens at a vertical loading of 50 N for 60,000 cycles at a frequency of 1.2 Hz. [14].

Microtensile Test Procedure

Restored teeth were sectioned longitudinally and bucco-lingually to rectangular rods of 1 mm thickness from the cavity floor of restorations (Isomet 1000, Buehler, USA). The specimens were attached to a Bencor Multi-T testing apparatus (which was modified by Bernard Ciucchi, Danville Engineering Co, Danville, CA, USA) with cyanoacrylate adhesive (Zapit, DVA, Anaheim, CA, USA), then subjected to failure in tension using universal testing machine (Microtensile tester, BISCO, Inc, Schaumburg, IL, USA) at a cross-head speed of 1 mm/min to determine the µTBS (n=20). The exact dimensions of each fractured specimen were determined using a digital caliper (Model CD-6BS, Mitutoyo, Japan) and µTBS values were calculated in MPa.

Statistical Analysis

The results were analyzed at a significance level of 0.05 using two-way ANOVA and Tukey's multiple comparison tests. Two-way ANOVA test was used to analyze the effects of the two experimental factors, that is, the type of adhesive and the aging regimen. Tukey's multiple comparison test was also performed to determine the significance between adhesive systems. All statistical analyses were carried out using the SPSS 17.0 (SPSS Inc, Chicago, IL, USA) software system.

Failure Mode Analysis

After microtensile testing, bond failure sites were observed visually with a stereomicroscope (Olympus SZ4045 TRPT, Osaka, JAPAN) at 50x magnification to determine failure modes. Classification of failure mode was made as follows; a, adhesive failure between dentin and resin; c, cohesive failure in the resin; d, cohesive failure in dentin; m, mixed failure (including adhesive failure between dentin and resin and cohesive failure of resin or dentin).

3. Results and Discussion

Microtensile bond strength tes*t*

The µTBS values for the groups are described in Table 2. Mean µTBS results were significantly affected by adhesive type ($p<0.05$), not the aging conditions ($p>0.05$). In control groups, the statistically significance differences were obtained among mean µTBS results of both self-etch (CSE, CPB, SSE, PRL, FLB), and total-etch adhesive systems (SMP, OPS, SB). The homogeneity of variance was analyzed using Kolmogorov-Smirnov and Shapiro-Wilk tests. The test didn't showed a significant difference at $p>0.05$. Therefore, the parametric statistic was subjected to further analysis.

For control groups, highest bond strength values were obtained with SMP, CSE and FLB ($p<0.05$). SSE showed the lowest bond strength value in control, but not statistically different from other bonding groups (CPB, PRL, OPS and SB) ($p>0.05$). When specimens were subjected to TC/ML, CSE exhibited the highest bond strength, but no significant difference existed between CSE and PRL and SB ($p>0.05$). After TC/ML, no significant difference existed between mean µTBS values of SSE and some adhesive groups (CPB, FLB, SMP and OPS), but the mean µTBS value of SSE was significantly lower than CSE, SB and PRL adhesive groups ($p<0.05$).

For all adhesive systems, bond strengths were lower when TC/ML was performed, but no significantly differences were observed between control group and TC/ML group, except for FLB and SMP. According to the results, the decrease of bond strength values in FLB and SMP adhesives were statistically important after TC/ML ($p<0.05$).

Analysis of the fracture modes

The results of fracture modes in all groups are shown in Table 3. For all adhesives, the most frequent pattern of failure was adhesive failure in both control and TC/ML groups. In the CSE, FLB, PRL and SMP groups, adhesive failure was found in a higher percentage area in TC/ML group than control group. After aging, only CSE showed cohesive failure in dentin (5%).

Strong and durable adhesion to the tooth substrate is critical to the long-term clinical success of direct and indirect resin-bonded restorations. The teeth in the oral cavity are constantly subjected to temperature changes, chewing loads, and chemical attacks by acids and enzymes that may cause degradation in the bonding interface of a restored tooth. The establishment of an *in vitro* methodology capable of reproducing some *in vivo* challenges is crucial for better understanding of adhesive materials behavior [15]. However, there are a limited number of studies evaluating the combine effect of thermal and mechanical load cycling on µTBS of different dentin adhesives, which are currently used.

In this study, influence of thermal and mechanical load cycling on µTBS of eight different dentin adhesives was tested in class V cavities. Most often, bonding performances of dental adhesives are tested on bovine enamel and dentin. In an effort to simulate clinical conditions and to enhance human applicability in the present study, human molars were used and the microtensile test method was measured before and after TC/ML. Microtensile testing has been used for evaluation of the bond strength of different adhesive system for many years. This test has several advantages over conventional tensile tests: better stress distribution at the bonding area, improved comparison of data from peripheral and central dentin, and the ability for collection of multiple micro specimens from each tooth [16]. Further, the microtensile test is believed to reduce cohesive failure and generally results in only adhesive failures.

In the present study, µTBS sticks were used before and after artificial aging. Stick-shaped specimens are simple to prepare and when compared to a dumbbell shape with a rectangular testing region had similar bond strengths, stress concentrations and failure locations [17]. One study reported that specimen substrate, shape, and thickness all have a significant influence on the µTBS results [18]. Same authors revealed that regardless of the dental substrate and of the specimen cross-section, sticks tended to give higher values of bond strength than hourglasses [18]. This may be explanation that the trimming method, by placing an extra-stress at the interface, may in fact weaken the adhesive bond. However, no pretesting failure was obtained for all groups in our study.

In the current study, which subjected samples to thermal and mechanical load aging, was designed to simulate clinical situations while trying to avoid some of the usual hurdles of clinical studies. The use of thermocycling with microtensile test method has been thoroughly investigated in the literature [1, 3, 6, 7]. Thermal cycling simulates the introduction of hot and cold extremes in the oral cavity and shows the relationship of the linear coefficient of thermal expansion between tooth and restorative material [3]. The quantity of cycles and the temperatures used seem to be the major difference among different studies [6, 7]. In this study, 5,000 cycles were used as an average of recent studies [6, 19]. The use of intermediary baths and different temperatures has been described but the use of ISO standardization (5°-55°C) allows for a better comparison between studies. On the other hand, special designed chewing simulator was used in this project for mechanical loading [20]. The simulation of the masticatory cycle has been studied to evaluate the wear and adhesion properties of dental biomaterials and/or restoration techniques [1, 6]. In microtensile evaluations, load is applied with different tips, loading sets, number of cycles and load forces. Several factors, such as the type of tooth, age, and gender, make it difficult to simulate *in vivo* chewing forces. Similar to some previous studies using chewing simulators, a force of 50 N was chosen to simulate the average constant load during mastication [6, 21].

The values obtained in this study were lower when compared to the results obtained using flat dentinal surfaces. The possible explanation could be the effect of the cavity configuration factor [1]. The C-factor is the ratio of the bonded surface area to the unbounded or free surface area. One study reported that 20% reduction in the bond strength of class II cavity walls compared to flat dentinal surfaces [22]. As the ratio becomes largest in the class V cavity, the competition between polymerization shrinkage and adhesion between the resin and dentin is maximized, when placing resin composite. There are numerous bond strength studies in the literature that evaluate flat surfaces, however, these studies unfortunately do not relate to more critical and demanding clinical conditions, such as high C-factor cavities. On the other hand it was reported that the depth of the dentin substrate could also affect the bond strength values. In our study, the tubules in the cavity floor are perpendicular to the cavity preparation, which effects the formation of resin tags negatively. This may have been the reason for the lower bond strength values compared to tubules parallel to the interface as reported by some authors [23].

The results of our study are in accordance with some other previous ones, which showed reduction in the bond strength when thermal and mechanical, loading applied together [1, 6, 24]. In this presented study, all the adhesives tested, bond strengths were lower when TC/ML was performed, except CPB, OPS and SB, which had higher bond strength values after artificial aging. However, it didn't observe a difference between bond strength values of control and TC/ML groups except for FLB and SMP bonding systems. Recently, Bedran-de-Castro et al. [6] reported that the µTBS of a total-etch adhesive at the cervical margins of Class II resin restorations decreased when 100,000 load cycling (50 N) was applied together with 2000 thermal cycling. Frankenber et al. [25] also reported that increasing the amount of TC/ML stress leads to a reduction in the µTBS of self-etch and total-etch adhesives. The varying results may be due to the adhesive system used, cavity shape, and differences in both the force and the number of cycles applied to specimens.

In this study, CSE Bond showed the highest bond strengths after TC/ML compared to other adhesive systems. CSE Bond is a fluoride-free, well-established and well-documented two-step self-etching adhesive that contains 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) as a functional monomer. The effectiveness of CSE on the dentinal surfaces is mainly related to penetration of the adhesive monomers. The monomer 10-MDP can readily adhere to residual hydroxyapatite in the hybrid layer, and this bond was reported to be very stable [24]. In addition to the self-etching effect on dentin, it is reported that the specific functional monomer 10-MDP is capable of forming strong ionic bond with calcium and can chemically interact with remaining HA crystals. This seems to contribute to the adhesive potential of CSE Bond.

CPB and FLB are fluoride-releasing two-step self-etch adhesive systems evaluated in this study. The chemical formulation of CPB is very similar to that of CSE Bond, with the exception of the antibacterial monomer (MDPB) content. Bonding stability of CPB was attributed to an antibacterial monomer, 12-methacryl oyloxydodecylpyridinium bromide (MDPB). It was previously reported that the slow fluoride release from CPB reduced the solubility of calcium phosphates within the hybridized smear layer, and the resultant hybrid layer provided more stable bonding to dentin over time [26]. This interaction may be explains better performance of CPB after artificial aging. On the other hand, FLB showed significantly lower bond strengths after TC/ML. It may have resulted from weak self-adhesive ability of the self-etch adhesive. Since, the FLB belongs to the category of "mild" self-etch primers [27]. It was suggested that application of TC/ML may lead to deterioration of the filler-resin matrix interface which may occur rapidly following water sorption, upon the subsequent formation of siliceous hydrogels around the ion-leachable glass fillers [27]. However, the significantly lower bond strength values in dentin obtained with FLB may be due to the composition or application conditions of the adhesive.

PRL is other two step self-etch adhesive examined in this study also showed similar results with CSE and FLB, after TC/ML. PRL does not contain fluoride, but it was reported that monomer GPDM (the smallest of all possible phosphate dimethacrylates) of the resin material affected bond strength positively [28].SSE is the last self-etch adhesive were evaluated in this study exhibited the worst µTBS values before and after TC/ML. The poor performance of SSE may be due to the complex application nature of the adhesive, water/acidic monomer ratio in an aqueous mixture, which might not be stable for each application [29]. SSE can be categorized as a two-step self-etch system, but differs from other two-step systems, as the self-etching step involves the application of two solutions. First, Liquid A, a HEMA-water solution (and not a self-etching primer), is applied. Second, this solution is mixed in situ with Liquid B to activate the self-etching process [28]. However, the increase or decrease in water concentration may affect the degree of ionization of the acidic monomer [29]. Therefore, the acidic adhesive of SSE contains TEGDMA, which absorbed more amount of water after polymerization than Bis-GMA.

In the current study, SMP which is a three-step adhesive system showed the highest bond strengths compared to other adhesive systems before TC/ML; but showed significantly lower bond strengths after TC/ML. In the literature, it is known that the primer of the adhesive system used in this study consists of HEMA (2-hydroxyethyl methacrylate) and co-monomers of polyalkenoic acid, allowing a more effective penetration [31]. In accordance to this, De Munck et al. [3] stated that the bonding effectiveness of both the two-step self-etch and the three-step etch-and-rinse version adhesives was not affected by water storage and thermocycling. On the contrary, Zhang et al. [30] reported that the use of acids for the required period in the etching step did not modify the mechanical properties of the dentine matrix; however, after long storage periods in water these properties may be affected, decreasing durability. We evaluated the bond strengths of both the self-etch and the total-etch adhesive systems, after specimens were subjected to both TC and ML for simulating the oral cavity challenges, such as the thermal changes and chewing forces. Therefore, our results were not compatible with those of other studies who reported higher bond strengths with SMP, after application of different artificial aging methods [3, 8, 9]. Moreover, the lower bond strength results of SMP after TC/ML may have been cause some factors, such as technique sensitive application conditions or different chemical composition of three-step adhesive system...

OPS and SB are two-step etch-and-rinse adhesives showed slight increased after TC/ML. Two-step etch-and-rinse adhesive systems are more technique sensitive compared to the two-step self-etch adhesive systems. Problems include the combination of hydrophilic and hydrophobic monomers into a single solution compromising the function of each component [28]. OPS and SB are an adhesive based on a HEMA/alcohol mixture and has been shown to be very technique sensitive, but SB able to obtain high bond strength values to dentin in our study when compared to other total-etch adhesives [32]. The results of SB were also comparable to those of CSE Bond after TC/ML. Toledano et al. suggested that if dentin is acid-etched, alcohol-based adhesive systems showed higher bond strength after mechanical loading [32]. The application of acetone produces little solvation force, further affecting the infiltration of resin monomers, while alcohol produces progressively higher solvation pressures that develop at increasing rates [33, 34]. The total-etch alcohol-based adhesive systems used in this investigation (OPS and SB) are thought to maintain the collagen fibrils in an expanded condition after the evaporation of solvents, thus improving infiltration of the monomers [35].

Table 1: Adhesive Systems used in the study

Adhesive Systems	Composition
Clearfil SE [CSE] (Kuraray Co. Ltd., Tokyo, Japan) (Lot 61961)	**Primer:** 10-MDP, HEMA, hydrophilic dimethacrylate, camphorquinone, N,N-diethanol-p-toluidine, water**Adhesive:** 10-MDP, HEMA, bis-GMA, dimethacrylate, camphorquinone, N,N-diethanol-p-toluidine, silica
Clearfil Protect Bond [CPB] (Kuraray Co, Ltd. Tokyo, Japan) (Lot 61207)	**Primer:** 10-MDP, MDPB, HEMA, hydrophilic dimethacrylate, camphorquinone, N,N-diethanol p-toluidine, water **Adhesive:** 10-MDP, MDPB, bis-GMA, HEMA, dimethacrylate, sodium fluoride, camphorquinone, N,N-diethanol p-toluidine, silica
FL Bond II [FLB] (Shofu Inc., Kyoto, Japan) (Lot 0309)	**Primer:** Water, ethanol, carboxylic acid monomer, phosphoric acid monomer **Adhesive:** S-PRG filler, UDMA, TEGDMA, 2-HEMA
Prelude Dental Adhesive [PRL] (Danville, San Ramon, CA, USA) (Lot 17472)	**Primer:** HEMA, GPDM, ethanol, pink colorant, water **Adhesive:**Dimethacrylate, HEMA, GPDM, initiators, silica, barium glass, $NaSiF_6$, ethanol
ScotchBond SE [SSE] (3M ESPE, St. Paul, MN, USA) (Lot 9BW)	**Primer:** Water, HEMA, Surfactant, pink colorant**Adhesive:** UDMA, TEGDMA, TMPTMA, HEMA phosphates, MHP, bonded zirconia nanofiller, camphoriquinone
Scotchbond Multi-Purpose [SMP] (3M. ESPE, St. Paul, MN, USA) (Lot N133000)	**Etchant:** 35% H_3PO_4 **Primer:** HEMA, polyalkenoic acid polymer**. Adhesive:**Bis-GMA, HEMA, tertiary amines
Adper Single Bond Plus [SB] (3M ESPE, St. Paul, MN, USA) (Lot 9XT)	**Etchant:** 35%H_3PO_4 **Adhesive:**BisGMA, HEMA, dimethacrylates, ethanol, water, polyacrylic and polyitaconic acids, silica
Optibond Solo Plus [OSP] (Kerr Corp., Orange, CA, USA) (Lot 3653616)	**Etchant:** 35% H_3PO_4**Adhesive:** ethanol, alkyl DMA resin, HEMA

10-MDP:10-methacryloyloxydecyl dihydrogenphosphate, **MDPB:** 12-Methacryloyloxydodecylpyridinium bromide, **HEMA:** 2-hydroxyethyl methacrylate, **Bis-GMA:** bisphenol A diglycidyl methacrylate, **S-PRG:** surface reaction type pre-reacted glass ionomer, **UDMA:** urethane dimethacrylate or 1,6-di (methacryloyloxyethylcarbamoyl)-3,3′,5-trimethylhexaan, **TEGDMA:** triethylene glycol dimethacrylate, **TMPTMA:** trimethylolpropanetrimethacrylate, **GPDM:** glycerol phosphate dimethacrylate

Table 2: Mean (±standard deviation-SD) µTBS values [MPa], minimum (Min) and maximum (Max) of the control and thermal/mechanical bonding groups.

Study Groups		Control			Thermal and mechanical		
		Min	Max	Mean	Min	Max	Mean
Self-Etch	CSE	15.40	39.20	29.8±7.0[ab]	11.70	40.20	25.8±9.2[abc]
	CPB	6.60	29.20	16.0±6.6[def]	10.24	26.40	16.8±5.0[def]
	FLB	19.40	34.80	26.1±4.8[abc]	11.60	27.00	18.0±5.6[def]
	PRL	14.50	28.90	21.6±4.9[cde]	8.30	29.30	19.1±7.3[cde]
	SSE	3.60	30.60	14.3±8.8[ef]	7.60	15.70	10.7±2.5[f]
Total-Etch	SMP	23.10	37.40	30.9±4.6[a]	7.20	28.30	15.4±5.7[def]
	OPS	10.00	24.90	15.0±3.8[def]	9.10	27.60	17.6±7.0[def]
	SB	10.30	30.80	20.0±6.4[cde]	15.30	28.70	22.3±5.0[bcd]

Table 3: Failure modes of the specimens after the micro tensile testing (Percentage)

Groups		Mode of Failure							
		Control				Thermal and mechanical			
		a	c	d	m	a	c	d	m
Self-Etch	CSE	85	-	-	15	90	-	5	5
	CPB	95	-	-	5	95	-	-	5
	FLB	80	-	5	15	90	-	-	10
	PRL	85	-	5	10	95	-	-	5
	SSE	90	-	-	10	90	-	-	10
Total-Etch	SMP	85	5	-	10	95	-	-	5
	OPS	95	-	-	5	95	-	-	5
	SB	90	-	-	10	85	-	-	15

Conclusion

As a conclusion of this study, the authors have to accept the null hypothesis, as artificial aging decreased (but not significantly) the µTBS of many total-etch or self-etch adhesive systems examined. The dentin bond strengths of some different adhesive systems did adversely affect by thermal and mechanical load cycling. However, results vary greatly with adhesive system type. The results obtained from this study; *in vitro* conditions simulating oral conditions (short-term) to identify the most resistant self-etch and total-etch dentin adhesive systems have clinical significance in terms of dentin bond strength. Within the limitation in this study, CSE-CPB-PRL bonding agents from all self-etch adhesive systems which two bottles and SB-OPS bonding agents from all total-etch adhesive systems which two bottles when simulating short-term oral environment showed clinically satisfactory results.

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