Mestrado Integrado em Medicina Dentária

Faculdade de Medicina da Universidade de Coimbra

1 2 9 0 FACULDADE DE MEDICINA UNIVERSIDADE DE COIMBRA

Air abrasion effect on dentin bond strength: systematic review

Inês Augusto Roque

Orientador: Doutora Alexandra Vinagre

Coorientador: Prof. Doutor João Carlos Tomás Ramos

Coimbra, julho 2020

Mestrado Integrado em Medicina Dentária

Faculdade de Medicina da Universidade de Coimbra

Air abrasion effect on dentin bond strength: systematic review

ROQUE, I.[1], RAMOS, J.[2], VINAGRE, A.[3]

1 Master's student of Dental Medicine, Faculty of Medicine, University of Coimbra, Coimbra, Portugal

2 Assistant Professor of Integrated Master in Dentistry, Faculty of Medicine, University of Coimbra, Operative Dentistry Institute

3 Assistant Lecturer of Integrated Master in Dentistry, Faculty of Medicine, University of Coimbra, Operative Dentistry Institute

Área de Medicina Dentária

Faculdade de Medicina da Universidade de Coimbra

Av. Bissaya Barreto, Bloco de Celas

3000-075 Coimbra, Portugal

Tel.: +351 239 249 151/2

Fax: +351 239 402 910

E-mail: ines_a_roque@hotmail.com

Coimbra, julho 2020

TABLE OF CONTENTS

1. RESUMO

Introdução: Previamente à aplicação do sistema adesivo, diferentes pré-tratamentos da dentina podem ser realizados com o objetivo de aumentar as forças à dentina e, consequentemente, o sucesso clínico a longo prazo. O jateamento é um destes pré-tratamentos.

Objetivo: Considerando que as opiniões podem divergir quanto à utilização de jateamento previamente à adesão, o presente estudo teve como objetivo fazer uma revisão sistemática da literatura científica disponível para estudos laboratoriais que avaliam o desempenho da adesão de diferentes sistemas adesivos quando a superfície dentinária é pré-tratada com jateamento.

Materiais e métodos: As pesquisas bibliográficas foram realizadas em cinco bases de dados: PubMed, Cochrane Library, Dentistry and Oral Sources Database através da EBSCOhost, Web of Science e LILACS. Foram incluídos apenas estudos in vitro que avaliaram as forças de adesão à dentina de dentes posteriores pré-tratados através de jateamento com óxido de alumínio e/ou glicina. Os estudos incluídos foram avaliados quanto ao risco de viés e a revisão segue as normas PRISMA.

Resultados: Um total de vinte e três estudos in vitro foram incluídos e processados para extração de dados. A avaliação do risco de viés dos estudos incluídos resultou na classificação dos estudos como baixo, médio e alto risco de viés. Resultados não homogéneos foram obtidos a partir dos dados relatados nos artigos avaliados. Sendo que, os principais resultados dos estudos in vitro incluídos nesta revisão revelaram que o jateamento não modificou significativamente as forças de adesão à dentina, independentemente da estratégia adesiva utilizada.

Conclusões: Dentro das limitações desta revisão sistemática, a evidência in vitro sugere que o uso de jateamento não aumenta nem diminui as forças de adesão à dentina, daí que pareça ser um passo desnecessário.

Palavras-chave: Jateamento; Óxido de Alumínio; Glicina; Dentina; Força de adesão; Revisão Sistemática.

2. ABSTRACT

Introduction: Prior to bonding procedures, different dentin pre-treatments can be used with the purpose of increasing bond strength performances of adhesive systems and, consequently, long-term clinical success. Air abrasion being one of these pre-treatments.

Aim: Considering that opinions may diverge regarding using air abrasion prior to bonding, the present study aimed to make a systematic review of the available scientific literature for laboratory studies that assessed the bonding performance of different adhesive systems when dentin surface was pre-treated with an air abrasion procedure.

Materials and methods: Literature searches were performed in five databases: PubMed, Cochrane Library, Dentistry and Oral Sources Database via EBSCOhost, Web of Science and LILACS. Only in vitro studies that evaluated the dentin bond strength of posterior teeth pre-treated with air abrasion with aluminum oxide and/or glycine were included. The included studies were assessed for risk of bias and the review follows the PRISMA statement.

Results: A total of twenty-three in vitro studies were included and processed for data extraction. An assessment of the risk of bias in the studies provided a result that classified the studies evaluated as low, medium, and high risk of bias. Inhomogeneous results were depicted from data reported in the included studies**.** Since main findings of the in vitro studies included in this review revealed that air abrasion did not significantly modified bond strength to dentin regardless of adhesive system strategy employed.

Conclusions: Within the limitations of this systematic review, the in vitro evidence suggests that the use of air abrasion does not seem to enhance or impair bond strength to dentin, appearing to be an unnecessary step.

Keywords: Air Abrasion, Dental; Aluminum Oxide; Glycine; Dentin; Dental bonding; Systematic Review.

3. INTRODUCTION

Achieving effective bonding to dentin is still a major challenge because of the heterogeneous nature of this tissue (1,2) and the intimate connection with pulpal tissue by means of fluid-filled tubules. Once under constant outward pressure, this fluid renders the exposed dentine surface naturally moist and thus intrinsically hydrophilic. This hydrophilicity definitely represents one of the major challenges for the interaction of adhesives with dentin (2).

The fundamental mechanism of bonding to dentin is essentially based upon an exchange process involving replacement of minerals by resin monomers, which upon *in situ* polymerization become micro-mechanically interlocked in the created microporosities (3–5). In dentin, this process is called 'hybridization' being primarily based on diffusion mechanisms and involving the formation of the hybrid layer, (3,4,6). The stability and durability of the bonded interface depends on the creation of a reliable, compact and homogenous, hybrid layer (7). In addition, predictability of the restorative treatment in terms of clinical performance, especially in the long-term, depends on achieving a stable bonding interface (8).

The performance of adhesive bonding to dentin is based on their interaction with the smear layer. During cavity preparation, rotatory or manual instrumentation produces organic and inorganic debris at dentin surface in the form of smear layer and smear plugs. Depending on the preparation technique, the smear layer varies in size and structure (2,4). Nevertheless, the presence of the smear layer acts as a physical barrier against the penetration of adhesive monomers (5) and impair bond strength to dentin (1,4).

Currently, two main strategies to promote adhesion of composite resins to dental substrates are identified: etch-and-rinse adhesive systems which remove the smear layer and self-etching adhesive systems which dissolve and incorporate the smear layer maintaining it as the substrate for the bonding (4,6,7). The main difference between the two approaches is the application of a preliminary and separate etching step for etch-and-rinse systems. Despite differences in etching, the other fundamental steps for adhesion are priming and bonding that can be either separate or combined, depending on the adhesive system (3).

The etch-and-rinse adhesives are technically more sensitive since one of the most delicate steps relates precisely to the acid etching, rinsing and the drying phase. It has been widely stated that the demineralized collagen network must be kept loosely arranged during adhesive procedures to allow proper resin monomer infiltration. Actually, a certain amount of water is crucial to prevent the exposed collagen mesh from collapsing, while an over-wet or over-dry condition may weaken the resin-dentin bond (2).

Self-etch approach eliminates the rinsing phase and it does not require wet-bonding, which not only makes it more user-friendly, implying a faster application procedure, but also reduces the technique-sensitivity, when compared with etch-and-rinse adhesives (3–5). Another important advantage of the self-etch approach is the absence or, at least, lower incidence of post-operative sensitivity experienced by patients (4). In general, self-etch adhesives have the advantage to demineralize and infiltrate the tooth surface simultaneously to the same depth, theoretically ensuring complete penetration of the adhesive (3,4).

The latest marketed group of materials called universal or multimode adhesive systems exhibit as their main feature the possibility to be applied according to different adhesion strategies: etch-and-rinse, self-etch, or selective enamel-etch, which allows the clinician to decide what protocol is most appropriate for the cavity being prepared (8,9). Research evidenced that bond strength of mild universal adhesives could be optimized by using the selective enamel-etch strategy (8,9).

Above all, three-step etch-and-rinse and two-step self-etch adhesive strategies continue to demonstrate the highest performance as most simplified one-step adhesives were shown to be the least durable (2,5,7).

Prior to bonding procedures, different dentin pre-treatments can be used with the purpose of increasing bond strength performances of adhesive systems and, consequently, long-term clinical success modifying the dentin surface (10,11). Various dentin-cleansing protocols, both chemical and/or mechanical, have been proposed to optimize resin monomer penetration into the collagen network. Regarding chemical cleansing agents, the most common agents include the use of phosphoric acid, chlorhexidine digluconate, sodium hypochlorite, ethylene diamine tetra acetic acid (EDTA) and hydrogen peroxide. Other treatments are based on mechanical approaches, including air abrasion, vibration and mechanical cleansing with pumice (12–15).

Air abrasion or sandblasting technique has been used in dentistry for minimally invasive cavity preparation, removal of decayed tissue, repair of existing restorations, or preparation of interfaces for adhesive by mechanical alteration of the dental hard tissues (10,11,16,17).

Air abrasion is a mechanical pre-treatment technique that consists of striking the tooth surface with abrasive particles in a fine stream of compressed air. As the particles, propelled by a stream of compressed dry air, collide with dentin, the kinetic energy of the particles is released, resulting in microscopic fractures, since it causes a removal of small amounts of tooth structure (11,13,15–17). This preparation is able to produce surface roughness that increases the area available for adhesion which can increase the bond strength of restorations to dentin (10,11,14–18). Furthermore, it increases dentin wettability and therefore facilitates the infiltration of the adhesive system into the dentin providing additional mechanical retention (13). In addition, removal of the smear layer by abrasion can also improve infiltration of the resin monomers into the dentin, contributing to bond strength improvement as well (10,18).

As a disadvantage, it is believed that residual powder particles on the dentin surface can also influence the penetration of the adhesive (13,19). Thereby, any dentin prophylaxis method should be efficient while leaving no detrimental remnants of the cleaning agent, that can present a risk for the adhesion success (13).

Aluminum oxide is the mainly investigated type of particle used for this type of dentin pre-treatment (20). In spite of the possibility that the powder cloud generated during sandblasting may be potentially dangerous for both the dentist and the patient, it has been demonstrated that the amount of dust that is produced is not enough to represent a hazard for human health and can be easily controlled with adequate suction and complete field isolation with rubber dam (13,17).

However, the efficiency of the technique relies on many parameters, including particle size, air pressure, time of application, distance from the handpiece to the dentin surface, nozzle angle and tip diameter (16,17,21).

Considering that opinions may diverge regarding using air abrasion prior to bonding, the present study aimed to make a systematic review of the available scientific literature for laboratory studies that assessed the bonding performance of different adhesive systems when dentin surface was pre-treated with an air abrasion procedure.

4. MATERIALS AND METHODS

This systematic review was performed following the recommendations of Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) (22).

The research strategy was formulated according to the PICO (Population, Intervention, Comparison, Outcome) strategy: "Is immediate or long-term dentin bond strength affected when its surface is pre-treated with an air abrasion technique?" (Table 1).

TABLE 1. PICO strategy

Population/problem	Dentin
Intervention	Dentin treated with an air abrasion technique
Comparation	No air abrasion treatment
Outcome	Bond strength evaluation

4.1. Search strategy

The studies included in this systematic review were obtained from PubMed, Cochrane Library, Dentistry and Oral Sources Database via EBSCOhost, Web of Science and LILACS up to June 2020. The search strategy used for each database is shown in Table 2.

4.2. Data selection

For this systematic review, only studies which met the following inclusion criteria were selected: (a) in vitro studies; (b) dentin air abrasion with aluminum oxide and/or glycine; (c) dentin bond strength evaluation with reported mean values; (d) posterior teeth; (e) articles written in English, Portuguese or Spanish. Exclusion criteria were as follows: (a) bovine teeth; (b) primary teeth; (c) caries removal with air abrasion.

The titles and abstracts retrieved were analysed to identify potentially eligible studies. All titles and abstracts were examined by two reviewers independently to find relevant studies. The full texts of the relevant studies were independently assessed in duplicate by two review authors. Any disagreement regarding the eligibility of the included studies was discussed and the opinion of a third reviewer was obtained when necessary.

TABLE 2. Search strategy for each database

Database	Search Strategy
PubMed	(((((((("tooth"[MeSH Terms]) OR tooth) OR "dentin"[MeSH Terms]) OR dentin) OR dentine)) AND ((((((((((("aluminum oxide"[MeSH Terms]) OR "aluminum oxide") OR "aluminium oxide") OR "alumina powder") OR "glycine"[MeSH Terms]) OR glycine) OR "glycine powder") OR cojet) OR "air abrasion, dental"[MeSH Terms]) OR "air abrasion") OR sandblast*) OR "air polishing")) AND ((((((((((bond strength) OR dentin bond strength) OR microtensile bond strength) OR shear bond strength) OR microshear bond strength) OR tensile bond strength) OR "dentin bonding agents"[MeSH Terms]) OR bonding agents) OR "dental bonding"[MeSH Terms]) OR "adhesive interface")) NOT ((((("ceramics"[MeSH Terms]) OR ceramic) OR "dental implants"[MeSH Terms]) OR “dental implants”) OR "orthodontic brackets"[MeSH Terms]) OR “orthodontic brackets”)
Cochrane Library	#1 MeSH descriptor: [Tooth] explode all trees #2 MeSH descriptor: [Dentin] explode all trees #3 (tooth):ti,ab,kw #4 (dentin):ti,ab,kw #5 (dentine):ti,ab,kw #6 #1 OR #2 OR #3 OR #4 OR #5 #7 MeSH descriptor: [Aluminum Oxide] explode all trees #8 MeSH descriptor: [Glycine] explode all trees #9 MeSH descriptor: [Air Abrasion, Dental] explode all trees #10 (“aluminum oxide”): ti,ab,kw #11 (“aluminium oxide”): ti,ab,kw #12(“alumina powder”): ti,ab,kw #13 (glycine):ti,ab,kw #14 (“glycine powder”): ti,ab,kw #15 (cojet):ti,ab,kw #16 (“air abrasion”): ti,ab,kw #17 (sandblast*):ti,ab,kw #18 (“air polishing”): ti,ab,kw #19 #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 #20 MeSH descriptor: [Dentin-Bonding Agents] explode all trees #21 MeSH descriptor: [Dental Bonding] explode all trees #22 (bond strength): ti,ab,kw #23 (dentin bond strength):ti,ab,kw #24 (microtensile bond strength):ti,ab,kw #25 (shear bond strength):ti,ab,kw #26 (microshear bond strength):ti,ab,kw #27 (tensile bond strength):ti,ab,kw #28 (bonding agents): ti,ab,kw #29 ("adhesive interface"): ti,ab,kw # 30 #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 #31 MeSH descriptor: [Ceramics] explode all trees #32 MeSH descriptor: [Dental Implants] explode all trees #33 MeSH descriptor: [Orthodontic Brackets] explode all trees #34 (ceramic):ti,ab,kw #35 (“dental implants”): ti,ab,kw #36 (“orthodontic brackets”):ti,ab,kw #37 #31 OR #32 OR #33 OR #34 OR #35 OR #36 #38 #6 AND #19 AND #30 NOT #37
Dentistry and Oral Sources Database via EBSCOhost	(tooth OR dentin OR dentine) AND (“aluminum oxide” OR “aluminium oxide” OR “alumina powder” OR glycine OR “glycine powder” OR cojet OR “air abrasion” sandblast* OR “air polishing”) AND (bond strength OR dentin bond strength OR microtensile bond strength OR shear bond strength OR microshear bond strength OR tensile bond strength OR bonding agents OR "dental bonding" OR "adhesive interface") NOT (ceramic OR “dental implants” OR “orthodontic brackets”)
Web of Science	TS=(tooth OR dentin OR dentine) AND TS=("aluminum oxide" OR "aluminium oxide" OR "alumina powder" OR glycine OR "glycine powder" OR cojet OR "air abrasion" sandblast* OR "air polishing") AND TS=(bond strength OR dentin bond strength OR microtensile bond strength OR shear bond strength OR microshear bond strength OR tensile bond strength OR bonding agents OR "dental bonding" OR "adhesive interface") NOT TS=(ceramic OR "dental implants" OR "orthodontic brackets")
LILACS	(mh:(tooth) OR tw:(tooth) OR mh:(dentin) OR tw:(dentin) OR tw:(dentine)) AND (mh:(“aluminum oxide”) OR tw:(“aluminum oxide”) OR tw:(“aluminium oxide”) OR tw:(“alumina powder”) OR mh:(glycine) OR tw:(glycine) OR tw:(“glycine powder”) OR tw:(cojet) OR mh:(“air abrasion, dental”) OR tw:(“air abrasion”) OR tw:(sandblast*) OR tw:(“air polishing”)) AND (tw:(bond strength) OR tw:(dentin bond strength) OR tw:(microtensile bond strength) OR tw:(shear bond strength) OR tw:(microshear bond strength) OR tw:(tensile bond strength) OR mh:("dentin bonding agents") OR tw:(bonding agents) OR mh:(“dental bonding”) OR tw:(“dental bonding”) OR tw:(“adhesive interface”)) AND NOT (mh:(ceramic) OR tw:(ceramic) OR mh:(“dental implant”) OR tw:(“dental implants”) OR mh:("orthodontic brackets") OR tw:(“orthodontic brackets”))

4.3. Data extraction

The studies that fulfilled the inclusion criteria were processed for the extraction of data. Descriptive and quantitative information was collected, including name of the first author, year of publication, teeth type, sample size, adhesive system used, composite used, intervention groups, bond strength method, aging method, bond strength values for control and test groups, predominant failure mode, outcomes, powder type of particle, particle size, pressure, duration, distance and angle.

The extraction of the information was done by two independent authors using a standard form. A consensus meeting was always held to confirm the agreement and to resolve disagreement among the reviewers.

4.4. Quality assessment

Two reviewers assessed the methodological quality of each included in vitro study by undergoing risk of bias across studies using guidelines previously reported in a systematic review of in vitro studies (9). The eight parameters evaluated were: teeth randomization, teeth free of caries, materials used according the manufacturer's instructions, blinding of the examiner, samples with similar dimensions, presence of a control group, assessment of the failure mode, and sample size calculation. Each parameter received a ''Yes'' (Y) if the details were reported in the paper; if the information was not provided, the parameter received a ''No'' (N). Articles that reported "Yes" in one to three parameters were classified as having a high risk of bias, four or five items as a medium risk of bias, and six to eight items as a low risk of bias.

5. RESULTS

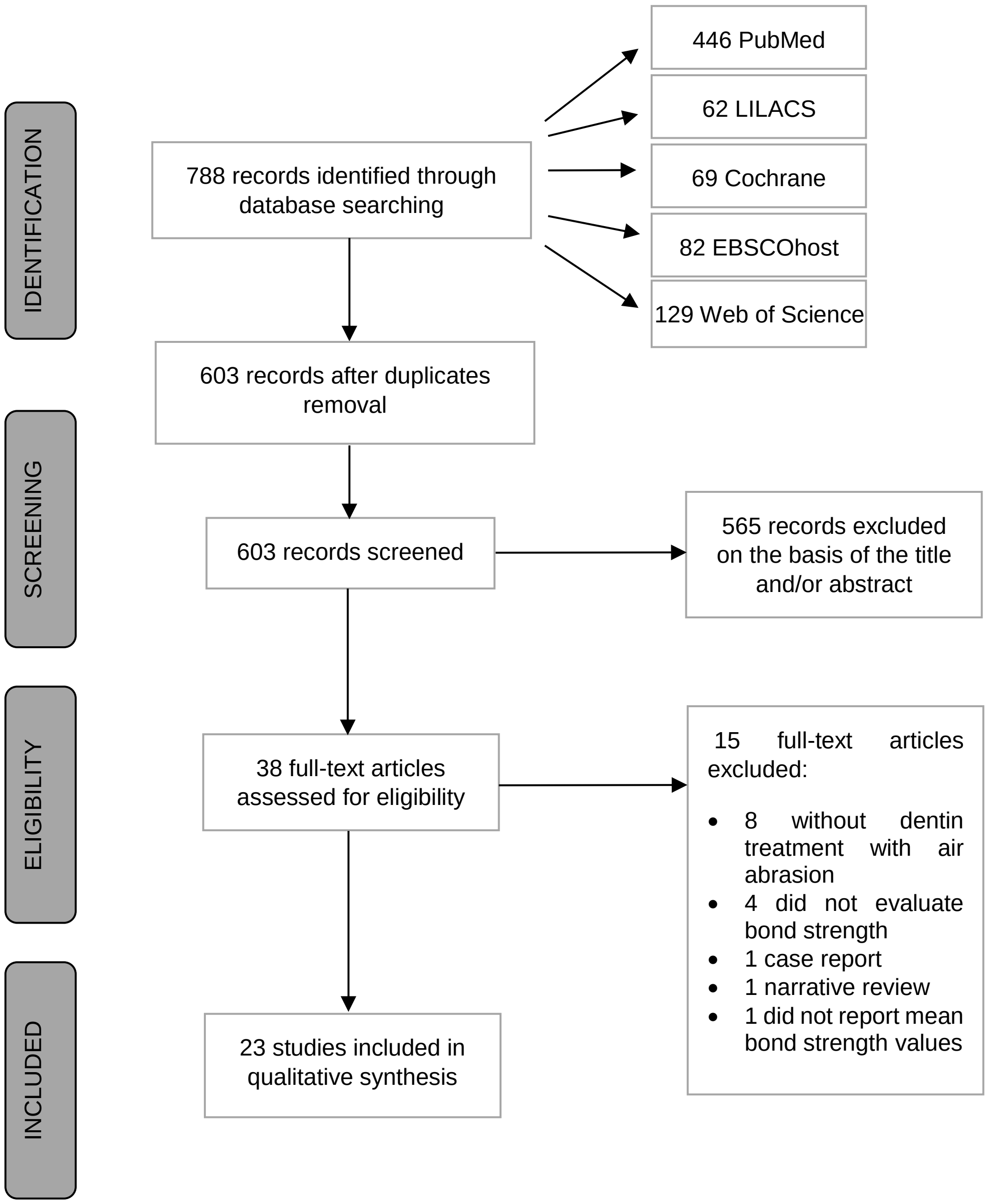

FIGURE 1 Flowchart of study selection process

5.1. Search results

The flowchart of the study selection process is presented in Fig. 1. The literature electronic search resulted in a total of 788 records. After removing duplicates, 603 records were screened for title and abstract, and 565 articles were excluded. A total of 38 papers were selected for full-text reading. Of these articles, 15 studies were further excluded (reasons reported in Fig. 1). After the final stage of selection, 23 studies were included and processed for data extraction.

5.2. Air-abrasion parameters of the included studies

Out of all the studies included, twenty-two studies reported the use of aluminum oxide powder and one study used glycine powder. The particle size ranged from 25 to 50 µm. Air pressure ranged from 6.5 to 160 psi. Duration of air abrasion ranged from 3 to 60 seconds. Distance of jet to dentin surface ranged from 1 to 50 millimetres. Angle between jet and dentin surface was reported in 11 studies as 45 or 90 degrees (Table 3).

5.3. General description of included studies

The main characteristics of the included studies are described in Table 4. All studies included the use of human molars, either they were specified as third molars or not.

Only one study included in this review investigated the effect of glycine powder on dentin bonding. It was concluded that air abrasion with this powder did not significantly affected dentin bonding for almost all the adhesives, except for the AdheSE adhesive system that exhibited significantly lower microtensile bond strengths when air abrasion was performed (23).

Different types of adhesive systems (etch-and-rinse, self-etch and universal) and restorative materials were used in each study. Inhomogeneous results were depicted from data reported in the studies. Since twelve studies demonstrated that, despite of the adhesive system employed, air abrasion with aluminum oxide did not significantly enhance or impair bond strength to dentin for all intervention groups (12,18,24–33). Two other studies reported a significant decrease in bond strength to dentin after air abrasion, also for all intervention groups (34,35). The remaining studies varied their results between the intervention groups (20,23,24,36–40), as can be confirmed in the Table 4. The Scotchbond Universal adhesive was evaluated in the Sutil et al. study (10) and it was applied in self-etch and etch-and-rinse modes. It was demonstrated that the behaviour of the adhesive was dependent on the bonding strategy that was used. For etch-and-rinse mode, air abrasion with aluminum oxide significantly increased microtensile bond strength of Scotchbond Universal adhesive system to dentin, otherwise for self-etch mode an increase was also observed, although not significantly.

Different bond strength test methods were used in the evaluated studies, including tensile bond strength (TBS), shear bond strength (SBS) and microtensile bond strength (µTBS) tests. The predominant test implemented was µTBS test, which was used in twelve studies (10,20,23,26,27,29,30,35–38,40). The SBS and TBS tests were used in nine (12,18,24,25,28,32–34,39) and two (31,41) studies, respectively.

Some studies used their own protocol for sample aging. Four studies employed thermocycling (18,32,37,39), and two studies employed long-term water storage for twelve months in one study (27) and for ninety or one hundred and eighty days in another study (36). In the study of Freeman et al. thermocycling induced a decrease in the shear bond strength for all restorative groups but it was only significant for the group without air abrasion and using the etch-and-rinse adhesive (18). For the studies applying water storage, it was verified a statistically significant decrease in mean bond strengths to dentin for all groups.

Failure mode of the interface was analysed by a stereomicroscope and/or a scanning electron microscope (SEM). These failure modes were classified into three main types, adhesive failure at the interface, cohesive failure within either the resin or dentin and mixed failure with combination of both. In general, adhesive failure was the dominant failure mode.

Parameters such as powder particle size, device pressure and moisture content of dentin have been compared in some studies. For particle size (20,35,39,41) and moisture content (33,39) there was no statistically significant difference in bond strength to dentin. On the other hand, the comparison of pressure between 120 psi and 160 psi for one study did not show statistically significant difference in bond strength to dentin (24), but for the other study the higher pressure showed a statistically significant increase in bond strength to dentin (39).

5.4. Risk of bias across studies

Of the ten studies included, twelve presented a low risk of bias, ten showed a medium risk of bias and one showed a high risk of bias. The outcome of the risk of bias analysis are described in Table 5, according to the parameters considered in the analysis. The studies scored particularly poorly for the parameters blinding of the operator and sample size calculation that were only reported by one study.

TABLE 3 Air abrasion related parameters of the included studies

Authors, year	Treatment powder	Intraoral air abrasion device	Particle size (µm)	Pressure	Duration (s)	Distance (mm)	Angle
D'Amario et al., 2017	Al_2O_3	(Micerium)	50	2 bar (29 psi)	10	50	90°
Santos et al., 2017	Al_2O_3	MicroEtcher Intraoral Sandblaster IIA (Danville Materials)	50	87 psi	10	20	NR
Sutil et al., 2017	Al_2O_3	Micro-jato jet (Bio Art)	50	60 psi	10	5	90°
Anja et al., 2015	Al_2O_3	KaVo Sonicflex 2003 L (KaVo)	50	80 psi	15	NR	90°
Pahlavan et al., 2013	Al_2O_3	NR	50	50 Psi	60	6	NR
Freeman et al., 2012	Al_2O_3	NR	50	3 bar (44 psi)	8	2	90°
Zimmerli et al., 2011	Al_2O_3	(Sandman ApS)	25	NR	5	1	NR
Yazici et al., 2009	Al_2O_3	PrepStar (Danville Materials)	27	120psi	5	2	NR
Burnett Jr et al., 2008	Al_2O_3	Microjato Plus (BioArt)	25 50	60 psi	10	2	NR
Souza-Zaroni et al., 2008	Al_2O_3	Mach 4.1 (Kreativ Inc.)	27.5	60 psi	NR	2	90°
de Oliveira et al., 2007	Al_2O_3	Air Touch Cavity Detection and Treatment System, Midwest Dental (Dentsply Sirona)	27	50 psi	20	2	45°
França et al., 2007	Al_2O_3	MicroEtcher (Bioart)	50	60 psi	10	5	NR
Frankenberger et al., 2007	Glycine	Prophyflex (KaVo)	NR	NR	10	5	NR
Motisuki et al., 2006	Al_2O_3	MicroEtcher (Danville Materials)	27 50	75 psi	60	1	90°
Van Meerbeek et al., 2003	Al_2O_3	Prep Start (Danville Materials)	27	6.5 psi	10	2	45°
Chaves et al., 2002	Al_2O_3	MicroEtcher (Danville Materials)	50	60 psi	10	5	NR
Burnett et al., 2001	Al_2O_3	Mach 5 (Kreativ Inc.)	27.5	80 psi	10	< 2	NR
Pilo et al., 2001	Al_2O_3	MicroEtcher (Danville Materials)	50	85 psi	3	NR	NR
Manhart et al., 1999	Al_2O_3	KCP 1000 Whisperjet unit (American Dental Technologies)	27 50	120 and 160 psi	6	5	90°
Manhart et al., 1999	Al_2O_3	KCP 1000 Whisperjet unit (American Dental Technologies)	50	120 psi	6	5	90°
Rinaudo et al., 1997	Al_2O_3	KCP Whisperjet 1000 (American Dental Technologies)	50	120 and 160 psi	NR	8	90°
Roeder et al., 1995	Al_2O_3	KCP-2000 (American Dental Technologies)	27 50	120 psi	NR	NR	NR
Los & Barkmeier, 1994	Al_2O_3	MicroEtcher (Danville Materials)	50	60 psi	NR	NR	NR

Al_2O_3, aluminum oxide; NR, not reported.

TABLE 4 Descriptive analysis of the included studies

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
							Control group	Test group		
D'Amario et al., 2017 (37)	Third molars	40 (5)	E&R: OptiBond FL (OFL); OptiBond Solo Plus (SO); Prime & Bond NT (PB); Riva Bond LC (RB) Herculite XRW Ultra	G1: OFL G2: Al_2O_3 + OFL G3: SO G4: Al_2O_3 + SO G5: PB G6: Al_2O_3 + PB G7: RB G8: Al_2O_3 + RB	µTBS	Thermocycling (30000 cycles, 5-55°C, 30 s)	G1: 18.31 ± 6.72 G3: 16.49 ± 4.61 G5: 27.68 ± 4.98 G7: 14.47 ± 5.75	G2: 35.51 ± 8.41 G4: 32.60 ± 7.31 G6: 33.36 ± 9.98 G8: 28.73 ± 7.06	SEM Mixed	Air abrasion significantly increased µTBS, except for PB
Santos et al., 2017 (42)	Molars	90 (12)	SE: Scotchbond Universal (SbU); Clearfil S Bond Plus (CS); Clearfil SE Bond (CSE) Filtek Supreme Ultra Universal Restorative	G1: SbU G2: Al_2O_3 + SbU G3: CS G4: Al_2O_3 + CS G5: CSE G6: Al_2O_3 + CSE	SBS	No aging	G1: 17.24 ± 7.03 G3: 13.83 ± 6.44 G5: 11.74 ± 4.01	G2: 22.68 ± 9.55 G4: 11.03 ± 4.15 G6: 14.21 ± 4.88	Stereomicroscope (10x) Adhesive G6: Mixed	Air abrasion did not show statistically significant difference in SBS
Sutil et al., 2017 (10)	Third molars	96 (8)	U: Scotchbond Universal (SbU) Filtek Z350	G1: SbU (SE) G2: Al_2O_3 + SbU (SE) G3: SbU (E&R) G4: Al_2O_3 + SbU (E&R)	µTBS	No aging	G1: 36.14 ± 6.63 G3: 30.10 ± 5.93	G2: 37.46 ± 13.42 G4: 44.26 ± 8.62	Stereomicroscope (40x) Adhesive	Air abrasion significantly increased µTBS of SbU applied in E&R mode. The application in SE mode increased µTBS values but not significantly
Anja et al., 2015 (26)	Molars	36 (12)	SE: G-bond (GB) Gradia Direct	G1: GB G2: Al_2O_3 + GB	µTBS	No aging	G1: 35.3 ± 12.8	G2: 35.8 ± 13.5	Stereomicroscope (NR) Adhesive	Air abrasion did not show statistically significant difference in µTBS
Pahlavan et al., 2013 (34)	Third molars	40 (10)	E&R: Single bond (SB) NR	G1: Carbide bur + SB G2: Al_2O_3 + SB	SBS	No aging	G1: 20.8 ± 6.76	G2: 14.98 ± 3.98	NR	Air abrasion significantly decreased SBS

Authors , year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
Freeman et al., 2012 (18)	Third molars	48 (16)	E&R: Adper Single Bond (AS) SE: Adper Prompt L Pop (AP) Z100	G1: AS G2: Al_2O_3 + AS G3: AS + thermocycling G4: Al_2O_3 + AS + thermocycling G5: AP G6: Al_2O_3 + AP G7: AP + thermocycling G8: Al_2O_3 + AP + thermocycling	SBS	Thermocycling (1000 cycles, 5°C-55°C, 30 s)	G1: 16.15 ± 4.64 G3: 9.57 ± 2.86 G5: 17.50 ± 5.36 G7: 11.52 ± 2.94	G2: 17.96 ± 5.99 G4: 14.96 ± 3.94 G6: 15.05 ± 3.93 G8: 14.59 ± 1.37	NR Adhesive	Air abrasion did not show statistically significant difference in SBS. Thermocycling decreased SBS, this decrease was statistically significant for G3
Zimmerli et al., 2011 (27)	Molars	80 (8)	E&R: OptiBond FL (OFL) SE: Clearfil SE Bond (CSE) Tetric EvoCeram	G1: Pumice + OFL G2: Diamond bur + OFL G3: Al_2O_3 + OFL G4: Pumice + OFL (12 M) G5: Diamond bur + OFL (12 M) G6: Al_2O_3 + OFL (12 M) G7: Pumice + CSE G8: Diamond bur + CSE G9: Al_2O_3 + CSE G10: Pumice + CSE (12 M) G11: Diamond bur + CSE (12 M) G12: Al_2O_3 + CSE (12 M)	µTBS	Water storage for 12 months (M)	G1: 46.5 ± 13.7 G2: 38.8 ± 12.1 G4: 36.3 ± 10.9 G5: 25.2 ± 12.3 G7: 41.1 ± 13.6 G8: 34.6 ± 11.8 G10: 30.9 ± 12.6 G11: 20.2 ± 9.2	G3: 42.5 ± 10.5 G6: 38.6 ± 10.0 G9: 39.5 ± 11.6 G12: 31.5 ± 14.6	Stereomicroscope (x50) and SEM. Cohesive	Air abrasion did not show statistically significant difference in µTBS. Storage significantly decreased µTBS.
Yazici et al., 2009 (28)	Mandibular molars	56 (14)	SE: Futura Bond NR (FB) Filtek Z250	G1: FB G2: Al_2O_3 + FB	SBS	No aging	G1: 14.44 ± 6.23	G2: 14.09 ± 5.94	NR	Air abrasion did not show statistically significant difference in SBS

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
Burnett Jr et al., 2008 (35)	Third molars	24 (20)	E&R: Single Bond (SB) Filtek Z250	G1: SB G2: Al_2O_3, 25µm + SB G3: Al_2O_3, 50µm + SB	µTBS	No aging	G1: 29.28 ± 4.50	G2: 21.66 ± 1.76 G3: 18.94 ± 2.16	SEM Mixed	Air abrasion significantly decreased µTBS. Particle size did not show statistically significant difference in µTBS
Souza-Zaroni et al., 2008 (29)	Third molars	110 (8)	SE: Adper Prompt L-Pop (AP) Filtek Z250	G1: Carbide bur + AP G2: Al_2O_3, standard handpiece + AP G3: Al_2O_3, supersonic handpiece + AP	µTBS	No aging	G1: 28.51 ± 6.29	G2: 31.70 ± 8.10 G3: 26.94 ± 8.44	Stereomicroscope (40x) Adhesive	Air abrasion did not show statistically significant difference in µTBS
de Oliveira et al., 2007 (38)	Third molars	96 (6)	SE: Tyrian SPE/OneStep Plus (TS); Clearfil SE Bond (CSE); UniFil Bond (UF) E&R: Single Bond (SB) Clearfil AP-X	G1: 600-grit SiC + TS G2: Al_2O_3 + TS G3: 600-grit SiC + CS G4: Al_2O_3 + CS G5: 600-grit SiC + UF G6: Al_2O_3 + UF G7: 600-grit SiC + SB G8: Al_2O_3 + SB	µTBS	No aging	G1: 29.9 ± 4.5 G3: 41.5 ± 2.9 G5: 20.4 ± 6.4 G7: 33.9 ± 4.7	G2: 21.2 ± 2.7 G4: 33.0 ± 5.0 G6: 30.1 ± 8.6 G8: 28.5 ± 1.3	SEM Mixed	Air abrasion did not show statistically significant difference in µTBS, except for UF adhesive, that significantly increased µTBS
França et al., 2007 (36)	Third molars	72 (6)	SE: Clearfil SE Bond (CSE); One-Up Bond F (OB) TPH Spectrum	G1: CSE G2: Al_2O_3 + CSE G3: CSE (90 D) G4: Al_2O_3 + CSE (90 D) G5: CSE (180 D) G6: Al_2O_3 + CSE (180 D) G7: OB G8: Al_2O_3 + OB G9: OB (90 D) G10: Al_2O_3 + OB (90 D) G11: OB (180 D) G12: Al_2O_3 + OB (180 D)	µTBS	Water storage for 90 or 180 days (D)	G1: 31.8 ± 7.5 G3: 19.8 ± 10.6 G5: 19.9 ± 6.2 G7: 29.4 ± 7.9 G9: 24.2 ± 8.7 G11: 17.8 ± 6.8	G2: 27.0 ± 7.2 G4: 26.7 ± 9.4 G6: 20.7 ± 7.5 G8: 28.2 ± 8.3 G10: 26.9 ± 8.4 G12: 21.0 ± 6.0	SEM Cohesive	Air abrasion did not show statistically significant difference in µTBS, except for CSE adhesive at 90 days of storage that significantly increased µTBS. Storage significantly decreased µTBS

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
Frankenberger et al., 2007 (23)	Third molars	60 (6)	E&R: Syntac (S); OptiBond FL (OFL); Single Bond Plus (SB) SE: AdheSE (ASE); Clearfil SE Bond (CSE); Clearfil Protect Bond (CP); One Coat Self-Etch Bond (OC); Xeno III (X); Clearfil S^3 Bond (CS); G-Bond (GB) Clearfil AP-X	G1: S G2: Gly + S G3: OFL G4: Gly + OFL G5: SB G6: Gly + SB G7: ASE G8: Gly + ASE G9: CSE G10: Gly + CSE G11: CP G12: Gly + CP G13: OC G14: Gly + OC G15: X G16: Gly + X G17: CS G18: Gly + CS G19: GB G20: Gly + GB	µTBS	No aging	G1: 41.3 ± 15.2 G3: 54.9 ± 14.8 G5: 33.5 ± 19.1 G7: 54.1 ± 16.4 G9: 73.0 ± 18.8 G11: 29.5 ± 14.7 G13: 29.9 ± 16.9 G15: 17.8 ± 9.8 G17: 19.7 ± 10.6 G19: 59.4 ± 17.4	G2: 42.6 ± 18.7 G4: 53.0 ± 16.0 G6: 32.6 ± 14.9 G8: 38.5 ± 18.3 G10: 64.5 ± 19.2 G12: 22.7 ± 18.6 G14: 36.5 ± 20.7 G16: 17.4 ± 7.2 G18: 17.2 ± 13.6 G20: 60.2 ± 18.3	SEM NR for all adhesives	Air abrasion with Gly did not show statistically significant difference in µTBS, except for AdheSE adhesive, that significantly decreased µTBS
Motisuki et al., 2006 (20)	Third molars	9 (3)	E&R: Adper Single Bond Z100	G1: Diamond bur G2: Al_2O_3, 27 µm G3: Al_2O_3, 50 µm	µTBS	No aging	G1: 40.34 ± 14.85	G2: 56,44 ± 18,05 G3: 49,95 ± 18,94	Stereomicroscope (25x) Adhesive	Air abrasion with 27 µm significantly increased µTBS. Air abrasion with 50 µm did not show statistically significant difference in µTBS. Particle size did not show statistically significant difference in µTBS.

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
Van Meerbeek et al., 2003 (40)	Third molars	90 (3)	E&R: OptiBond FL (OFL) SE: Clearfil SE (CSE) Z100	G1: 600-grit SiC + OFL G2: Diamond bur + OFL G3: Al_2O_3 + OFL G4: 600-grit SiC + CSE G5: Diamond bur + CSE G6: Al_2O_3 + CSE	µTBS	No aging	G1: 51.6 ± 19.6 G2: 59.6 ± 16.8 G4: 45.5 ± 16.6 G5: 37.7 ± 10.5	G3: 54.9 ± 16.3 G6: 54.1 ± 13.0	Stereomicroscope (50x) Mixed Adhesive: G4	Air abrasion did not show statistically significant difference in µTBS, except for SE adhesive system when compared to diamond bur that significantly increased µTBS
Chaves et al., 2002 (30)	Third molars	36 (3)	E&R: Prime & Bond NT (PB) SE: Clearfil Mega Bond (CMB); Etch & Prime 3.0 (EP) TPH Spectrum	G1: PB G2: Al_2O_3 + PB G3: CMB G4: Al_2O_3 + CMB G5: EP G6: Al_2O_3 + EP	µTBS	No aging	G1: 38.4 ± 9.3 G3: 21.1 ± 4.3 G5: 12.8 ± 4.2	G2: 38.6 ± 12.3 G4: 25.7 ± 4.1 G6: 11.4 ± 3.6	NR	Air abrasion did not show statistically significant difference in µTBS
Burnett et al., 2001 (31)	Molars	23 (15)	E&R: Single Bond (SB) Z100	G1: Diamond bur + SB G2: Al_2O_3 + SB	TBS	No aging	G1: 17.52 ± 2.01	G2: 15.83 ± 1.51	Stereomicroscope (25x) Adhesive	Air abrasion did not show statistically significant difference in TBS
Pilo et al., 2001 (32)	Third molars	167 (14)	E&R: One Step (OS); Prime & Bond 2.1 (PB) Z100	G1: OS G2: Al_2O_3 + OS G3: PB G4: Al_2O_3 + PB	SBS	Thermocycling (1000 cycles, 5°C-55°C, 10 s)	G1: 11.81 ± 4.34 G3: 9.97 ± 6.97	G2: 9.54 ± 4.93 G4: 9.94 ± 6.05	NR	Air abrasion did not show statistically significant difference in SBS

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)	Analytical tool (magnification) Predominant failure mode	Outcomes
Manhart et al., 1999 (39)	Molars	260 (20)	E&R: Syntac Single-Component (SS) Tetric	Dentin surface dry: G1: SS G2: Al_2O_3, 50 µm, 120psi + SS G3: Al_2O_3, 50 µm, 160psi + SS G4: Al_2O_3, 27 µm, 160psi + SS Dentin surface moist: G5: SS G6: Al_2O_3, 50 µm, 120psi + SS G7: Al_2O_3, 50 µm, 160psi + SS	SBS	Thermocycling (1000 cycles, 5°C-55°C, 30 s)	G1: 13.2 ± 5.1 G5: 15.4 ± 2.1 G2: 16.2 ± 4.8 G3: 23.9 ± 5.2 G4: 21.8 ± 5.0 G6: 15.6 ± 4.4 G7: 17.1 ± 3.7	Stereomicroscope (x40) Adhesive	Air abrasion with 160 psi air pressure and bonded to dry dentin significantly increased SBS. 160 psi air pressure significantly increased SBS compared to 120 psi. Particle size and moisture content did not show statistically significant difference in SBS
Manhart et al., 1999 (33)	Molars	120 (10)	E&R: Syntac Single-Component (SS) Compoglass F	Dentin surface dry: G1: SS G2: Diamond bur + SS G3: Al_2O_3 + SS Dentin surface moist: G4: SS G5: Diamond bur + SS G6: Al_2O_3 + SS	SBS	No aging	G1: 20.0 ± 3.0 G2: 22.7 ± 3.6 G4: 20.2 ± 1.9 G5: 21.6 ± 3.1 G3: 21.4 ± 2.6 G6: 23.0 ± 2.6	Stereomicroscope (x40) Adhesive	Air abrasion and moisture content did not show statistically significant difference in SBS

Authors, year	Teeth type	Number of teeth (per group)	Materials: Adhesive(s) and composite resin(s)	Intervention groups	Bond strength method	Aging method	Mean bond strength (MPa ± SD)		Analytical tool (magnification) Predominant failure mode	Outcomes
Rinaudo et al., 1997 (24)	Molars	225 (15)	Resin-modified glass ionomer: Fuji II LC (FLC) E&R: Scotchbond Multi-Purpose Plus (SMP); One Step (OS) Herculite XRV	G1: FLC G2: Al_2O_3, 120 psi + FLC G3: Al_2O_3, 160 psi + FLC G4: OS G5: Al_2O_3, 120 psi + OS G6: Al_2O_3, 160 psi + OS G7: SMP G8: Al_2O_3, 120 psi + SMP G9: Al_2O_3, 160 psi + SMP	SBS	No aging	G1: 9.64 ± 2.74 G4: 14.06 ± 3.55 G7: 15.15 ± 4.93	G2: 6.94 ± 1.75 G3: 6.22 ± 1.59 G5: 15.57 ± 2.92 G6: 16.90 ± 1.75 G8: 14.76 ± 2.30 G9: 14.67 ± 2.81	NR	For Fuji II LC, air abrasion significantly decreased SBS. For One Step and Scotchbond Multi-Purpose Plus, air abrasion did not show statistically significant difference in SBS. Air pressure did not show statistically significant difference in SBS
Roeder et al., 1995 (41)	Third molars	NR	E&R: Optibond (OB) Herculite XRV	G1: OB G3: Al_2O_3, 27µm + OB G4: Al_2O_3, 50µm + OB	TBS	No aging	G1: 24.1 ± 8	G3: 21.8 ± 7 G4: 20.2 ± 3	NR	Air abrasion and particle size did not show statistically significant difference in TBS
Los & Barkmeier, 1994 (25)	Molars	180 (10)	E&R: All-Bond 2 (AB2); Scotchbond Multi-Purpose (SB); Prisma Universal Bond 3 (PU); Tenure Solution (TS); Amalgambond (AB); Mirage ABC (MABC) Prisma APH	G1: AB2 G2: Al_2O_3 + AB2 G3: PU G4: Al_2O_3 + PU G5: SB G6: Al_2O_3 + SB G7: TS G8: Al_2O_3 + TS G9: AB G10: Al_2O_3 + AB G11: MABC G12: Al_2O_3 + MABC	SBS	No aging	G1: 20.4 ± 2.0 G3: 15.7 ± 3.8 G5: 18.2 ± 1.6 G7: 11.7 ± 2.3 G9: 17.1 ± 3.5 G11: 10.2 ± 1.7	G2: 20.7 ± 1.6 G4: 19.3 ± 2.6 G6: 17.1 ± 1.2 G8: 11.9 ± 2.8 G10: 17.9 ± 2.4 G12: 11.2 ± 1.7	Only report cohesive failures in dentin	Air abrasion with Al_2O_3 did not show statistically significant difference in SBS

TBS, tensile bond strength; SBS, shear bond strength; µTBS, microtensile bond strength; E&R, etch-and-rinse; SE, self-etch; U, universal; NR, not reported; Gly, glycine; Al_2O_3, aluminum oxide; SEM, scanning electron microscope.

TABLE 5 Quality assessment and risk of bias

Authors, year	Teeth random ization	Teeth free of caries	Materials used according the manufacturer's instructions	Blinding of the examiner	Samples with similar dimensions	Control group	Assessment of the failure mode	Sample size calculation	Risk of bias
D'Amario et al., 2017	Y	Y	Y	N	Y	Y	Y	N	Low
Santos et al., 2017	Y	Y	Y	N	Y	Y	Y	N	Low
Sutil et al., 2017	Y	Y	Y	N	Y	Y	Y	Y	Low
Anja et al., 2015	Y	Y	Y	N	Y	Y	Y	N	Low
Pahlavan et al., 2013	Y	Y	N	N	Y	N	N	N	High
Freeman et al., 2012	N	Y	Y	Y	Y	Y	Y	N	Low
Zimmerli et al., 2011	N	N	Y	N	Y	Y	Y	N	Medium
Yazici et al., 2009	Y	Y	Y	N	Y	Y	N	N	Medium
Burnett Jr et al., 2008	Y	Y	Y	N	Y	Y	Y	N	Low
Souza-Zaroni et al., 2008	Y	Y	Y	N	Y	Y	Y	N	Low
de Oliveira et al., 2007	Y	Y	Y	N	Y	Y	Y	N	Low
França et al., 2007	Y	N	Y	N	Y	Y	Y	N	Medium
Frankenberger et al., 2007	Y	Y	Y	N	Y	Y	Y	N	Low
Motisuki et al., 2006	Y	Y	Y	N	Y	N	Y	N	Medium
Van Meerbeek et al., 2003	Y	Y	Y	N	Y	Y	Y	N	Low
Chaves et al., 2002	Y	Y	Y	N	Y	Y	N	N	Medium
Burnett et al., 2001	N	N	Y	N	Y	Y	Y	N	Medium
Pilo et al., 2001	Y	Y	Y	N	Y	Y	N	N	Medium
Manhart et al., 1999	Y	Y	Y	N	Y	Y	Y	N	Low
Manhart et al., 1999	Y	Y	Y	N	Y	Y	Y	N	Low
Rinaudo et al., 1997	Y	Y	Y	N	Y	Y	N	N	Medium
Roeder et al., 1995	Y	Y	N	N	Y	Y	N	N	Medium
Los & Barkmeier, 1994	N	N	Y	N	Y	Y	Y	N	Medium

6. DISCUSSION

Different strategies have been adopted to enhance the bond strength between adhesives and dentin. Since smear layer can compromise the clinical bonding effectiveness to dental substrates, numerous mechanical and chemical cleaning methods have been proposed, with air abrasion being a mechanical pre-treatment that can be used before bonding with the aim of removing debris and so improving the interfacial bond strength (43,44). The current systematic review aimed at answering the following question "Is immediate or long-term dentin bond strength affected when its surface is pre-treated with an air abrasion technique?" by the analysis of in vitro studies dealing with different air abrasion techniques in bond strength to dentin.

Main findings of the in vitro studies included in this review revealed that dentin bond strength was not significantly affected when its surface was pre-treated with air abrasion, regardless of the adhesive strategy employed. This could be verified in twelve of the included studies for all intervention groups. Two other studies indicated that the dentin bond strength was significantly decreased by air abrasion, also for all the intervention groups. Only one study included in this review investigated the effect of glycine powder on dentin bonding demonstrating that air polishing with this powder did not significantly affect dentin bonding for almost all the adhesives, only AdheSE, a two step self-etching adhesive system exhibited significantly lower microtensile bond strengths after air abrasion (23). To be able to draw conclusions more studies using glycine powder should be accomplished and evaluated.

Critical factors affecting the bond strength are the type of air abrasion and the air abrasion parameters used. There was a substantial methodological heterogeneity and incomplete information about air abrasion parameters in the included studies. It is important to recognize that several parameters inherent to the air abrasion system affects the efficiency of the air abrasion device (21). The heterogeneity of the reported results could be due to the differences in powder particle size and pressure used. Four studies evaluated the differences in using different particle sizes (20,35,39,41), and all of them indicated that the particle size has no significant influence on bond strength to dentin. The tendency for higher bond strength values with smaller particles, may be due to the fact that a greater number of small particles are thrown per second from the nozzle tip when compared to larger particles, and subsequently more particles contact the surface area, generating more irregularities and, in turn, increasing bonding surface and microretentions (20,35,41). Nevertheless, the SEM micrographs showed a similar surface morphology and increase of surface area irrespective to 27 or 50 µm powder sizes (20,39). Two studies evaluated the differences in using different pressures (24,39). In one study significantly higher bond strengths for 160 psi abraded specimens were achieved compared to 120 psi setting and the reason seems to be the larger surface area for bonding obtained with 160 psi (39). However, Rinaudo et al. (24), reported that air pressure did not significantly influence shear bond strengths.

Souza-Zaroni et al. (29), reported a better performance with a standard tip compared to a less diameter supersonic tip. When using the supersonic tip, the concentration of the same quantity of abrasive particles on a smaller area can result in a superior kinetic force on the dentin surface, compared to the greater diameter tip, that is able to produce deeper irregularities and in a greater quantity. In dentin, however, this kinetic force may have been excessive and possibly alter the substrate negatively, fact that had not occurred when applying the standard tip.

It would be an ergonomic advantage in time and handling if the additional step of acid etching could be excluded after dentin preparation with air abrasion since quality of adhesion and cavity sealing would not be impaired. In the literature, controversy exists concerning whether air abrasion creates a micro-retentive surface that is suitable to bonding so that acid etching is no longer necessary. In this review, some studies demonstrated that air abrasion alone does not eliminate the need for acid etch prior to applying an etch-and-rinse adhesive (24,33,40). Rinaudo et al. (24), explained that these findings could be due to two reasons. The first one is that the smear layer generated by the air abrasion interfere with the penetration into the dentin surface, and the second relates to the presence of aluminum oxide particles on the surface after air abrasion, which can induce dentin contamination interfering with the establishment of a stable hybrid layer. Two other studies showed that when acid etching was replaced by air abrasion, no significant changes in bond strength were observed (30,39). A possible explanation for this fact, given by authors, is that the acidity of the adhesives used was sufficient to partially dissolving the smear layer while the monomers infiltrate the collagen network, producing bond strength values comparable to previously demineralized dentin surface.

Scanning Electron Microscopy was used in some studies to evaluate the pre-treated dentinal surface micro-morphology (20,23,25,26,35,38–40). All studies exhibited an irregular dentin surface after air abrasion. Most of the studies revealed that air abrasion resulted in a dentin surface without any patent tubules that were blocked with smear layer. However, Anja et al. (26) reported that tubules were only partial occluded and Frankenberger et al. (23) stated that air abrasion with glycine resulted in removal of smear layer and open dentinal tubules could be observed. SEM was also applied to analyze dentin/adhesive interfaces micromorphology that exhibited hybrid layers and resin tags in all bonded interfaces (29,38). Previous studies demonstrated that air abrasion through the impact of countless high-energetic particles on dentin surface is able to produce a roughened surface, increasing dentin area available for wetting, enhancing the micromechanical retention and promoting the effectiveness of adhesion to dentin (14,45). Also, the superficial removal of the smear layer by air abrasion can increase the potential for penetration of the resin monomers into the dentin and consequently increase bond strength (30). However, in other previous studies, SEM evaluation confirmed the presence of smear layer in air abraded surfaces that must be removed for maximum bond strength (46) and surface roughness obtained with the air abrasion may not increase the adhesive bond strength since this is not the only factor affecting the bonding (47).

Freeman et al. (18), showed, through confocal micrographs, defects at the dentin-adhesive surface of thermocycled and air abraded specimens. These defects in thermocycled specimens include separation of the hybrid layer from the underlying dentin in which resin tags were located. In this case, resin tag formation may not contribute to bond strength where the hybrid layer becomes disconnected from the adjacent dentin following aging of the restoration. In fact, this separation may contribute for the decrease in shear bond strength reported. In air abraded specimens, defects in the hybrid layer were verified and there was no significant improvement in shear bond strength to dentin even though air abrasion increased the number, length and diameter of resin tags. A possible explanation is that air abrasion has been suggested to produce superficial maceration of the collagen fibers on dentin (48). This can weaken the superficial structure of the dentin and affect the quality of the hybrid layer (48) causing the formation of defects such as voids and clefts. Where air-abrasion has damaged the dentin surface, the penetration of biological fluids that affect hydration of the resin matrix and breakdown adhesion to the collagen fibers (49) may be increased and result in lower long term clinical durability.

Long-term bonding performance, after the specimens have been exposed to artificial aging, provides much more information in the prediction of the long-term clinical durability of resin-dentin bonding. Thermocycling and water storage are the most popular aging methods (50). In general, aging procedures caused a decrease in dentin bond strengths in all studies evaluated. However, bond strength values tended to remain higher, following aging, of the specimens for air abraded specimens allowing a speculation of its eventual protective effect.

Although thermocycling is one of the most widely aging procedure used, there is an apparent lack of a standardized protocol. This system is used to replicate the in vivo aging of restorative materials by exposing them to repeated cyclic to hot and cold temperatures in water baths to reproduce thermal changes occurring in the oral cavity. This process results in combined contraction/expansion stresses and accelerates chemical degradation of the interface, that can affect the mean values of bond strength to dentin (51,52). In this review, four studies used thermocycling procedures (18,32,37,39). The temperature was the same for all of them (5°- 55°C), but there were variations in the number of cycles and in the dwell time chosen. While most of the studies used 30 seconds dwell time (18,37,39) one used 10 seconds (32). The use of shorter dwell times (10 or 15 seconds) may simulate more accurately the abrupt changes of temperature that take place in the oral cavity (52). D' Amario et al., chosen 30000 cycles and the remain studies opted for 10000 cycles. A short thermocycling procedure of 500 cycles is of little use, this number of cycles is too low for an aging effect to be achieved, sometimes only very long thermocycling up to 100000 cycles can distinguish differences in bond durability of different adhesives (50,51).

Nevertheless, water aging is a very challenging process because the interface within the specimen is directly exposed to water and consequently easily penetrated. The cause of interface degradation has been attributed to the hydrolysis of demineralized collagen fibers that were not completely impregnated by resin, leading to a reduction in bond strength during long-term water storage (51). Both studies evaluating water storage concluded that this method significantly lowered bond strengths to dentin and also influenced fracture mode (27,36). Zimmerli et al., showed a reduction in the amount of cohesive failures in favour of adhesives ones and França et al., also showed a reduction in the amount of cohesive but an increase in the percentage of mixed fractures. After storage, specimens appeared more prone to interface detachment during specimen processing. It is possible that the interface degradation influenced the reduction in bond strength means and caused an increase in the percentages of adhesive/mixed fractures.

It is proposed to reject cohesive failure specimens from the statistical analysis, whether they are in dentin or in resin composite, and just select data from specimens with adhesive failure or mixed failure with small (< 10%) resin or dentin involvement for bond strength calculation (53). Regarding cohesive failure mode, they are not representative of an interface bond strength, since they represent breaking stresses resulting from different materials with different mechanical properties (53). Cohesive failure can be caused by numerous reasons, for example, errors in alignment of the specimen along the long axis of the testing device (54) and microcracks produced during cutting or trimming of the specimens (55). The inclusion of cohesive failures in dentin and composite into the statistical analyses, adds scatter in bond strength data (53). However, none of the included studies either excluded cohesive failure specimens or mentioned de percentage of resin or dentin involvement in mixed failures, which can be a reason for the differences in bond strength values and the inconsistent results among the included studies.

One limitation of this review is the degree of scientific evidence attained by the in vitro studies. The results should be interpreted with caution, due to the high heterogeneity observed and the inherent limitations of laboratory studies, which may not reflect an actual clinical situation. Some factors must be taken into account that could influence the bond strength in clinical environment, including pH and temperature cycling, masticatory stresses, as well as the moisture, which might contribute to degradation of the adhesive interface (49). Thus, the validity of bond strength tests to predict the clinical performance is questionable. Beyond that, mechanical tests can give valuable information which facilitates to define guidelines for application procedures (55).

A more recent approach in the air abrasion field is the use of a Bioglass 45S5 (BAG) powder, which is a bioactive calcium-sodium phosphate-phyllosilicate that may be used as a substitute for aluminum oxide in air abrasion systems. BAG retained on the dentin surface during the air-abrasion procedure will create a bioactive smear layer that reacts with body fluids, helping the formation of hydroxyapatite and the remineralization of dental hard tissues (56,57). Sauro et al. (57) demonstrated recently that the durability of resin-modified glass ionomer cements applied onto dentin air abraded with bioactive glass regardless the use of polyacrylic acid conditioner is not influenced by load cycling and/or prolonged aging in artificial saliva. These findings may represent an advantage and therefore this approach should be explored in future studies.

In the extension of this systematic review it is intended to perform a meta-analysis to do a quantitative synthesis in relation to air abrasion with aluminum oxide.

7. CONCLUSION

Despite the high heterogeneity and limitations, the in vitro literature seems to suggest that the use of air abrasion does not seem to enhance or impair bond strength to dentin, appearing to be an unnecessary step. However, recommendations for standardized testing methods are required to obtain relevant information and to understand the effects of dentin pre-treatment with air abrasion.

8. REFERENCES

1. Carvalho RM, Manso AP, Geraldeli S, Tay FR, Pashley DH. Durability of bonds and clinical success of adhesive restorations. Dent Mater. 2012 Jan;28(1):72–86.

2. Cardoso M V, de Almeida Neves A, Mine A, Coutinho E, Van Landuyt K, De Munck J, et al. Current aspects on bonding effectiveness and stability in adhesive dentistry. Aust Dent J. 2011 Jun;56 Suppl 1:31–44.

3. 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. Vol. 28, Operative dentistry. United States; 2003. p. 215–35.

4. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt KL. State of the art of self-etch adhesives. Dent Mater. 2011 Jan;27(1):17–28.

5. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res. 2005 Feb;84(2):118–32.

6. Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, et al. State of the art etch-and-rinse adhesives. Dent Mater. 2011 Jan;27(1):1–16.

7. Breschi L, Mazzoni A, Ruggeri A, Cadenaro M, Di Lenarda R, De Stefano Dorigo E. Dental adhesion review: aging and stability of the bonded interface. Dent Mater. 2008 Jan;24(1):90–101.

8. Cuevas-Suárez CE, da Rosa WL de O, Lund RG, da Silva AF, Piva E. Bonding Performance of Universal Adhesives: An Updated Systematic Review and Meta-Analysis. J Adhes Dent. 2019;21(1):7–26.

9. Rosa WL de O da, Piva E, Silva AF da. Bond strength of universal adhesives: A systematic review and meta-analysis. J Dent. 2015 Jul;43(7):765–76.

10. Sutil BG da S, Susin AH, da Silva Sutil BG, Susin AH, Sutil BG da S, Susin AH. Dentin pretreatment and adhesive temperature as affecting factors on bond strength of a universal adhesive system. J Appl Oral Sci. 2017;25(5):533–40.

11. Poggio C, Beltrami R, Colombo M, Chiesa M, Scribante A. Influence of dentin pretreatment on bond strength of universal adhesives. Acta Biomater Odontol Scand. 2017 Jan;3(1):30–5.

12. Santos MJMCMC, Bapoo H, Rizkalla AS, Santos GC, Santos Jr. GC. Effect of dentin-cleaning techniques on the shear bond strength of self-adhesive resin luting cement to dentin. Oper Dent. 2011 Sep;36(5):512–20.

13. Soares CJ, Pereira JC, Souza SJBB, Menezes MS, Armstrong SR. The effect of prophylaxis method on microtensile bond strength of indirect restorations to dentin. Oper Dent. 2012 Nov;37(6):602–9.

14. Rafael CF, Quinelato VV, Morsch CS, DeDeus G, Reis CM. Morphological Analysis of Dentin Surface after Conditioning with Two Different methods: Chemical and Mechanical. J Contemp Dent Pract. 2016 Jan 1;17(1):58–62.

15. Chaiyabutr Y, Kois JC. The effects of tooth preparation cleansing protocols on the bond strength of self-adhesive resin luting cement to contaminated dentin. Oper Dent. 2008;33(5):556-563.

16. Onisor I, Bouillaguet S, Krejci I. Influence of different surface treatments on marginal adaptation in enamel and dentin. J Adhes Dent. 2007 Jun;9(3):297–303.

17. Neuhaus KW, Ciucchi P, Donnet M, Lussi A. Removal of enamel caries with an air abrasion powder. Oper

Dent. 2010;35(5):538–46.

18. Freeman R, Varanasi S, Meyers IA, Symons AL. Effect of air abrasion and thermocycling on resin adaptation and shear bond strength to dentin for an etch-and-rinse and self-etch resin adhesive. Dent Mater J. 2012;31(2):180–8.

19. Atoui JA, Chinelatti MA, Palma-Dibb RG, Corona SAM. Microleakage in conservative cavities varying the preparation method and surface treatment. J Appl Oral Sci. 2010;18(4):421–5.

20. Motisuki C, Monti Lima L, Emi Sanabe M, Jacques P, Santos-Pinto L. Evaluation of the microtensile bond strength of composite resin restoration in dentin prepared with different sizes of aluminum oxide particles, using the air abrasion system. Minerva Stomatol. 2006;55(11–12):611–8.

21. Santos-Pinto L, Peruchi C, Marker VA, Cordeiro R. Effect of handpiece tip design on the cutting efficiency of an air abrasion system. Am J Dent. 2001 Dec;14(6):397–401.

22. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan;350:g7647.

23. Frankenberger R, Lohbauer U, Tay FR, Taschner M, Nikolaenko SA. The effect of different air-polishing powders on dentin bonding. J Adhes Dent. 2007 Aug;9(4):381–9.

24. Rinaudo PJ, Cochran MA, Moore BK. The effect of air abrasion on shear bond strength to dentin with dental adhesives. Oper Dent. 1997;22(6):254–9.

25. Los SA, Barkmeier WW. Effects of dentin air abrasion with aluminum oxide and hydroxyapatite on adhesive bond strength. Oper Dent. 1994;19(5):169–75.

26. Anja B, Walter D, Nicoletta C, Marco F, Pezelj Ribaric S, Ivana M. Influence of air abrasion and sonic technique on microtensile bond strength of one-step self-etch adhesive on human dentin. ScientificWorldJournal. 2015;2015:368745.

27. Zimmerli B, De Munck J, Lussi A, Lambrechts P, Van Meerbeek B. Long-term bonding to eroded dentin requires superficial bur preparation. Clin Oral Investig. 2012 Oct;16(5):1451–61.

28. Yazici AR, Karaman E, Ertan A, Ozgunaltay G, Dayangac B. Effect of different pretreatment methods on dentin bond strength of a one-step self-etch adhesive. J Contemp Dent Pract. 2009 Jan;10(1):41–8.

29. Souza-Zaroni WC, Chinelatti MA, Delfino CS, Pecora JD, Palma-Dibb RG, Corona SAM. Adhesion of a self-etching system to dental substrate prepared by Er:YAG laser or air abrasion. J Biomed Mater Res B Appl Biomater. 2008 Aug;86(2):321–9.

30. Chaves P, Giannini M, Ambrosano GMB. Influence of smear layer pretreatments on bond strength to dentin. J Adhes Dent. 2002;4(3):191–6.

31. Burnett LHJ, Conceicao EN, Pelinos JE, Eduardo CD. Comparative study of influence on tensile bond strength of a composite to dentin using Er:YAG laser, air abrasion, or air turbine for preparation of cavities. J Clin Laser Med Surg. 2001 Aug;19(4):199–202.

32. Pilo R, Cardash HS, Oz-Ari B, Ben-Amar A. Effect of preliminary treatment of the dentin surface on the shear bond strength of resin composite to dentin. Oper Dent. 2001;26(6):569–75.

33. Manhart J, Chen HY, Kunzelmann KH, Hickel R. Bond strength of a compomer to dentin under various surface conditions. Clin Oral Investig. 1999 Dec;3(4):175–80.

34. Pahlavan A, Mehmanchi M, Ranjbar Omrani L, Chiniforush N. Effect of Air Abrasion and Erbium-Doped Yttrium Aluminum Garnet (Er: YAG) laser preparation on Shear Bond Strength of Composite to Dentin. J lasers Med Sci. 2013;4(3):127–30.

35. Burnett Júnior LH, Silveira BL da, Masotti AS, Mota EG, Shinkai RSA. Influence of dentin surface pre-treatment on microtensile bond strength of a single-bottle adhesive TT - Influência do pré-tratamento superficial da dentina na resistência de união à microtração de um sistema adesivo de frasco único. 2008;23(4):325–9.

36. França FMG, Santos AJS, Lovadino JR, Franca FMG, dos Santos AJS, Lovadino JR. Influence of Air Abrasion and Long-term Storage on the Bond Strength of Self-etching Adhesives to Dentin. Oper Dent. 2007 May;32(3):217–24.

37. D'Amario M, Piccioni C, Di Carlo S, De Angelis F, Caruso S, Capogreco M. Effect of airborne particle abrasion on microtensile bond strength of total-etch adhesives to human dentin. Biomed Res Int . 2017;2017(no pagination).

38. de Oliveira MT, de Freitas PM, de Paula Eduardo C, Ambrosano GMB, Giannini M. Influence of Diamond Sono-Abrasion, Air-Abrasion and Er:YAG Laser Irradiation on Bonding of Different Adhesive Systems to Dentin. Eur J Dent. 2007 Jul;1(3):158–66.

39. Manhart J, Mehl A, Schroeter R, Obster B, Hickel R. Bond strength of composite to dentin treated by air abrasion. Oper Dent. 1999;24(4):223–32.

40. Van Meerbeek B, De Munck J, Mattar D, Van Landuyt K, Lambrechts P. Microtensile bond strengths of an etch&rinse and self-etch adhesive to enamel and dentin as a function of surface treatment. Oper Dent. 2003 Sep;28(5):647–60.

41. Roeder LB, Berry EA 3rd, You C, Powers JM. Bond strength of composite to air-abraded enamel and dentin. Oper Dent. 1995;20(5):186–90.

42. Santos MJM, Costa MD, Rêgo HMC, Rubo JH, Santos GC. Effect of surface treatments on the bond strength of self-etching adhesive agents to dentin. Gen Dent. 2017;65(4):e1–6.

43. Falkensammer F, Arnetzl GV, Wildburger A, Krall C, Freudenthaler J. Influence of different conditioning methods on immediate and delayed dentin sealing. J Prosthet Dent. 2014;112(2):204–10.

44. Oliveira SSA, Pugach MK, Hilton JF, Watanabe LG, Marshall SJ, Marshall GWJ. The influence of the dentin smear layer on adhesion: a self-etching primer vs. a total-etch system. Dent Mater. 2003 Dec;19(8):758–67.

45. Mujdeci A, Gokay O. The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin. J Prosthet Dent. 2004 Sep;92(3):245–9.

46. Chinelatti MA, Corona SAM, Borsatto MC, Ribeiro LF, Rocha RAS de S, Palma-Dibb RG. Analysis of surfaces and adhesive interfaces of enamel and dentin after different treatments. J Mater Sci Mater Med. 2007 Jul;18(7):1465–70.

47. Coli P, Alaeddin S, Wennerberg A, Karlsson S. In vitro dentin pretreatment: surface roughness and adhesive shear bond strength. Eur J Oral Sci. 1999 Oct;107(5):400–13.

48. Nikaido T, Yamada T, Koh Y, Burrow MF, Takatsu T. Effect of air-powder polishing on adhesion of bonding systems to tooth substrates. Dent Mater. 1995 Jul;11(4):258–64.

49. Amaral FLB, Colucci V, Palma-Dibb RG, Corona SAM. Assessment of in vitro methods used to promote adhesive interface degradation: a critical review. J Esthet Restor Dent. 2007;19(6):340–53; discussion 354.

50. Van Meerbeek B, Peumans M, Poitevin A, Mine A, Van Ende A, Neves A, et al. Relationship between bond-strength tests and clinical outcomes. Dent Mater. 2010 Feb;26(2):e100-21.

51. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res. 2005 Feb;84(2):118–32.

52. Morresi AL, D’Amario M, Capogreco M, Gatto R, Marzo G, D’Arcangelo C, et al. Thermal cycling for restorative materials: does a standardized protocol exist in laboratory testing? A literature review. J Mech Behav Biomed Mater. 2014 Jan;29:295–308.

53. Scherrer SS, Cesar PF, Swain M V. Direct comparison of the bond strength results of the different test methods: a critical literature review. Dent Mater. 2010 Feb;26(2):e78-93.

54. Cho B-H, Dickens SH. Effects of the acetone content of single solution dentin bonding agents on the adhesive layer thickness and the microtensile bond strength. Dent Mater. 2004 Feb;20(2):107–15.

55. Armstrong S, Geraldeli S, Maia R, Raposo LHA, Soares CJ, Yamagawa J. Adhesion to tooth structure: a critical review of “micro” bond strength test methods. Dent Mater. 2010 Feb;26(2):e50-62.

56. Sauro S, Watson TF, Thompson I, Toledano M, Nucci C, Banerjee A. Influence of air-abrasion executed with polyacrylic acid-Bioglass 45S5 on the bonding performance of a resin-modified glass ionomer cement. Eur J Oral Sci. 2012 Apr;120(2):168–77.

57. Sauro S, Watson T, Moscardó AP, Luzi A, Feitosa VP, Banerjee A. The effect of dentine pre-treatment using bioglass and/or polyacrylic acid on the interfacial characteristics of resin-modified glass ionomer cements. J Dent. 2018 Jun;73:32–9.