©Operative Dentistry, 2021, **46-1**, E21-E33

Airborne-particle Abrasion and Dentin Bonding: Systematic Review and Meta-analysis

VP Lima • KDA Soares • VS Caldeira • AL Faria-e-Silva • BAC Loomans • RR Moraes

Clinical Relevance

The literature reviewed suggests that airborne particle abrasion has no negative effects on the bond strength of resin-based materials to dentin and that a positive influence on dentin bond strength was only achieved in specific air-abrasion conditions.

SUMMARY

In this systematic review the authors investigated how airborne-particle abrasion (APA) using aluminum oxide affects the bond strength of resin-based materials to dentin. The search was performed in three databases. *In vitro* studies (Type of study) comparing the bond strength of resin-based materials (Outcome) to air-abraded (Intervention) compared with non–air-abraded (Comparison) human dentin (Population) were included (the PICOT elements are given parenthetically). From 5437 unique articles, 65 were read in full, 33 were included in the qualitative synthesis, and 32 were included in the meta-analysis. Methodologic quality and risk of bias were assessed. Comparisons were performed between air-abraded and control dentin groups by adopting a random-effects model (α=0.05). Additional analyses were carried out for the different parameters used in APA: type of surface treatment in the control group, particle size, air pressure, and APA duration. The bond strength to air-abraded dentin was favored only when the control surface was treated with a hand excavator. For particle size, APA was favored when the particle size was >30 μm and the controls were no treatment or hand excavator or when the particle size was ≤ 30 μm and the control was bur. In addition, the results favored air-abraded groups only when the pressure was > 5 bar and bur was used in the control group. No significant differences were observed for duration of APA. No comparison on bond strength considering the presence of aging conditions was possible in the included

Verônica P. Lima, DDS, MS, PhD candidate, Graduate Program in Dentistry, Federal University of Pelotas, Pelotas, Brazil

Karla D.A. Soares, DDS, Graduate Program in Dentistry, Federal University of Sergipe, Aracaju, Brazil

Vanderson S. Caldeira, DDS, School of Dentistry, Federal University of Pelotas, Pelotas, Brazil

André L. Faria-e-Silva, DDS, MS, PhD, professor, Graduate Program in Dentistry, Federal University of Sergipe, Aracaju, Brazil

Bas A.C. Loomans. DDS, MS, PhD, assistant professor, Department of Dentistry, Radboud University Medical Center, Nijmegen, The Netherlands

*Rafael R. Moraes, DDS, MS, PhD, professor, Graduate Program in Dentistry, Federal University of Pelotas, Pelotas, Brazil

*Corresponding author: Rua Gonçalves Chaves 457, 96015-560, Pelotas, RS, Brazil; e-mail: moraesrr@gmail.com

https://doi.org/10.2341/19-216-L

studies due to the low number of studies that aged the specimens. In conclusion, APA had no negative effects on the bond strength of resin-based materials to dentin and was able to improve the dentin bond strength only when the particle size was > 30 μm and air pressure was > 5 bar. PROSPERO registration protocol: CRD42018096128

INTRODUCTION

Airborne-particle abrasion (APA) is a procedure used for several applications in dentistry, with the first report dating back to the 1940s.[1] Different air-abrasion devices have been introduced to the market for applications including cavity preparation,[1-3] prophylaxis and removal of surface stains,[1] selective caries removal,[4] tribochemical coating,[5] and surface polishing or roughening.[6] APA involves propelling a well-defined, sharply focused stream of particles expelled from a small nozzle under high pressure against a surface. The fluid used is usually compressed air, and many particle types, such as sodium bicarbonate, glycine, and aluminum oxide, can be used depending on the intended goal of APA.[7,8] The particle size, pressure, and duration of APA may also vary depending on the clinical application[9-12] and affect the result of the abrasion process.

Depending on the abrasive particle, the kinetic energy of the accelerated hard particles may result in rapid substance removal on impact.[13] Whereas sodium bicarbonate is usually used for polishing procedures, APA with aluminum oxide is commonly used to prepare surfaces to enhance micromechanical retention of restorative materials, such as glass ceramics,[14,15] oxide ceramics,[16,17] and resin composites.[18,19] The objective is usually to increase the area for micromechanical interlocking of adhesive materials.[20-22] Despite a limited number of clinical studies, clinical applications of APA of dental substrates using aluminum oxide particles have been reported as a cleaning method, a pretreatment technique before adhesive luting of indirect restorations, and surface treatment before resin composite restorations.[23-25]

Despite the potential benefits for bonding restorative materials, APA has also been shown to produce surface flaws and microcracks that can compromise the strength of ceramic restorations.[26,27] Thus, evaluation of the effects of APA on human dentin is warranted. In several *in vitro* studies, investigators have examined the effect of APA on dentin[10,21,22,28-32] and have usually focused on applying air-abrasion to improve the bond strength of adhesive materials.[10,17,24,33-38] Large variability exists among the size of the abrasive particles used, as well as the time duration and pressure used in APA. Pooled *in vitro* data could help determine whether APA has a positive effect on dentin and ascertain whether the technique can be applied clinically to dentin surfaces without major concerns. The aim of this systematic review of *in vitro* studies, therefore, was to investigate how APA using aluminum oxide particles affects the bond strength of resin-based materials to human dentin. The null hypothesis was that APA does not have a negative effect on dentin bond strength.

METHODS AND MATERIALS

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[39] The review protocol was registered with the international database for systematic reviews – PROSPERO (protocol CRD42018096128). The PICOT elements were as follows: Population, human dentin; Intervention, air abrasion considering a procedure in which dentin surfaces were subjected to abrasive blasting by a stream of aluminum oxide particles propelled under high pressure with compressed air as the fluid; Comparison, non–air-abraded dentin; Outcome, bond strength of resin-based materials to dentin; and Type of study, *in vitro* tests.

Systematic Literature Search

The literature search aimed to identify all studies that evaluated the effect of APA using aluminum oxide particles on dentin. The search was systematically performed by two independent reviewers (VPL and VSC) using three online international scientific databases: The National Library of Medicine (MEDLINE/PubMed), ISI Web of Science, and Scopus. The search strategy used in PubMed is shown in Table 1. The strategy was adapted to the other databases accordingly. The final search was performed in October 2018. After the articles were searched, all were imported into Endnote X7 software (Thompson Reuters, Philadelphia, PA, USA) to remove duplicates.

Titles and abstracts were read to verify the inclusion criteria: *in vitro* studies that reported comparison between air-abraded and non–air-abraded dentin bond strengths. When the study did not clearly define the control group, the non–air-abraded group was considered the control. The following terms were considered in the inclusion criteria: “air abrasion,” “airborne particle abrasion,” “air polishing,” or “sandblasting.” Aluminum oxide particles

Table 1: *Search Strategy Used in PubMed and Adapted to the Other Databases*

	Search Terms
#3	Search #1 AND #2
#2	Dentin* OR Dental
#1	Air-Abrasion OR Air Abrasion OR Airborne Abrasion OR Airborne-Particle Abrasion OR Particle Abrasion OR Air Abrasion, Dental OR Abrasion, Dental Air OR Abrasions, Dental Air OR Air Abrasions, Dental OR Dental Air Abrasion OR Dental Air Abrasion OR Prophylaxis OR Sandblast* OR Air Polishing

were the only abrasive eligible for this review. Only studies that evaluated the bond strength of resin-based materials to sound dentin from human teeth exposed to APA were included. Studies that evaluated bovine dentin and abrasive particles other than aluminum oxide were excluded. Only articles published in English were considered, with no restrictions on year of publication. Any disagreement regarding the eligibility of the included studies was resolved through discussion and consensus, or a third reviewer (RRM) was consulted. Only studies that fulfilled all eligibility criteria were included. Whenever information relevant to eligibility was unavailable in the abstract or the abstract itself was unavailable, the article was selected for full-text reading. The reviewers manually searched the reference lists of the included articles for additional relevant studies.

Data Recorded From the Selected Studies

For each included study, the following data and information were recorded using a standard form in spreadsheet format (Excel for Mac version 16.31, Microsoft Corporation, Redmond, WA, USA): control group and its surface treatment, particle size, air-abrasion distance, angle with the surface during air-abrasion, air-abrasion pressure, air-abrasion duration, cleaning method or surface treatment after APA, type of bond strength test, bond strength mean values in MPa, standard deviations, and number of specimens tested.

Data Analysis

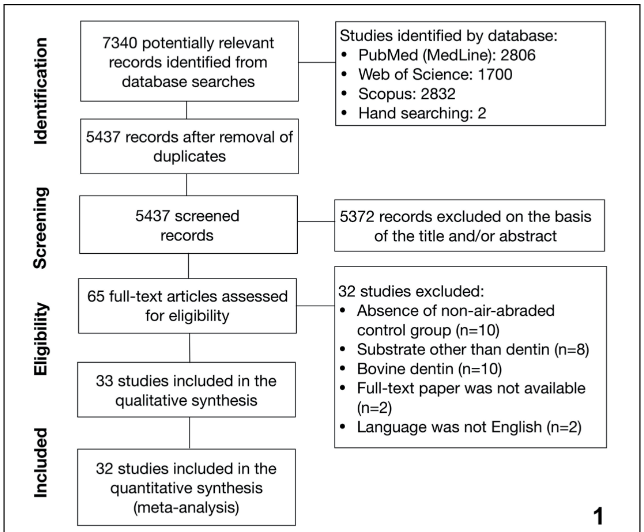
Pooled effect estimates were obtained by comparing the standardized mean difference between the air-abraded and control groups within each study with estimated 95% confidence intervals. The standardized mean difference was used to minimize differences in bond strength values measured by different methods, for example, shear or tensile tests. The analyses were performed by adopting a random-effects model using Review Manager version 5.1 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). As the studies adopted different surface treatments in the control groups, a meta-analysis was carried out considering the same intervention-control subgroups, that is, the control groups were separated according to their surface treatments: no treatment, bur, SiC abrasive paper, hand excavator, or acid etching. Additional analyses were carried considering the different air-abrasion parameters adopted, that is, the abrasive particle size ($\leq$30 μm or $>$30 μm), air pressure ($\leq$5 bar or $>$5 bar), APA duration ($\leq$10 seconds or $\geq$15 seconds) and presence of aging conditions (yes/no). All meta-analyses considered the same combinations of intervention-control groups. Statistical heterogeneity of the treatment effect among studies was appraised using the Cochran Q test, in which values $>$50% were considered to suggest substantial heterogeneity.[40] Multiple groups from the same study were analyzed according to the Cochrane guidelines formula for combining groups.[40]

Quality Assessment and Risk of Bias

The methodologic quality and risk of bias of the included studies was assessed according to Cochrane guidelines[40] and criteria adapted from previous studies[41,42] as follows: selection bias (random sequence generation), sample-size calculation, presence of a clearly defined control group, and performance and detection bias (blinding of operator/examiner). Each criterion was judged to have high, low, or unclear risk of bias, which was also used for quality assessment. The assessment of risk of bias was performed using Review Manager version 5.1.

RESULTS

The search resulted in the retrieval of 7340 articles, as shown in the study flowchart presented in Figure 1. After removing duplicates, 5437 unique publications were screened, of which 5372 were excluded because they did not meet the eligibility criteria. A total of 65 articles were assessed in full, including two found in the manual search. From these 65 publications, 32 were excluded for reasons detailed in Figure 1. The list of articles excluded after the eligibility screening is provided as supplementary



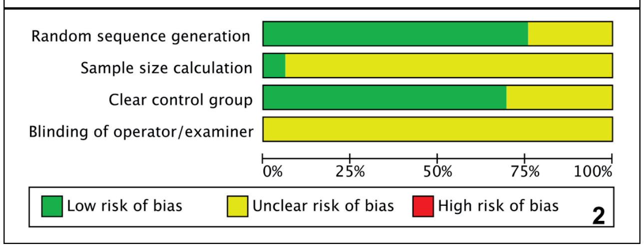


Figure 1. *Flowchart of the systematic review.*
Figure 2. *Risk of bias graph: proportion of studies with low, unclear, or high risk of bias for each item.*

material in the Appendix. A total of 33 studies were included in the qualitative synthesis, and 32 were included in the meta-analysis. One study that evaluated bond strength[43] was not included in the quantitative analysis because the standard deviation value was missing; nevertheless, this study reported similar bond strengths between air-abraded and control dentin.

Varied APA parameters were used across the studies: 70% used aluminum oxide particles with size >30 μm, the air pressure most commonly used was up to 5 bar (51.5%), and air-abrasion duration was usually up to 10 seconds (54.5%). All studies included in this review and the details of the air-abrasive procedures are provided in the Appendix. Only data that were within the scope of this study are reported. Regarding quality assessment (Figure 2), most included studies presented low risk of bias relative to random sequence generation, and the majority of studies presented a clearly defined control group. Sample-size calculation was reported in two studies, and blinding of operator/examiner was not reported in any of the included studies. The risk of bias for each item judged in each included study is shown in Figure 3.

The meta-analysis on dentin bond strength values considering the different combinations of intervention-control comparisons is presented in Figure 4. A significant difference was found between the groups favoring dentin subjected to APA compared with non–air-abraded dentin only when the control surface was treated with a hand excavator (p=0.02, I^2=67%). When the other control dentin surface treatments were considered (no treatment, bur, SiC paper, or acid etching), no significant differences between air-abraded and non–air-abraded dentin were detected.

Considering the APA parameter particle size (Figure 5), the results favored APA when the particle size was > 30 μm and the controls were no treatment (p=0.02, I^2=64%) and hand excavator (p<0.00001, I^2=0%). APA was also favored when the particle size was ≤30 μm and the control was bur (p=0.0004, I^2=0%). For the other control surfaces no significant differences between the experimental and control groups were observed. When the parameter air-abrasion pressure was considered in the meta-analysis (Figure 6), the results favored air-abraded groups only when the air pressure was >5 bar and bur was used to treat the control surfaces (p=0.01, I^2=0%), with no other significant differences. Two studies[44,45] did not report air pressure, thus were not considered in the subgroup analysis. Regarding the parameter APA duration (Figure 7), no significant differences were observed in bond strength between control and air-abraded dentin. Three studies did not report the duration of air abrasion.[46-48] and, in two studies, air-abrasion duration was not standardized since it depended on the removal of cement from the surface[20,49] or tooth preparation.[8,50]

It was not possible to perform a meta-analysis considering the presence of aging conditions in the studies as only four articles reported dentin bond strengths for immediate and aged groups.[45,49,51,52] Each study had a different type of control, hindering comparisons within the same combinations of intervention-control groups.

DISCUSSION

The null hypothesis tested was accepted since application of APA with aluminum oxide particles had no detrimental effect on the bond strength of resin-based materials to dentin in any of the meta-analyses. Previous studies have reported possible negative effects of APA on dentin characteristics. These studies showed that APA may result in more irregular[11,12,26,53-55] or rougher dentin surfaces compared with non–air-abraded dentin.[56-59] How-

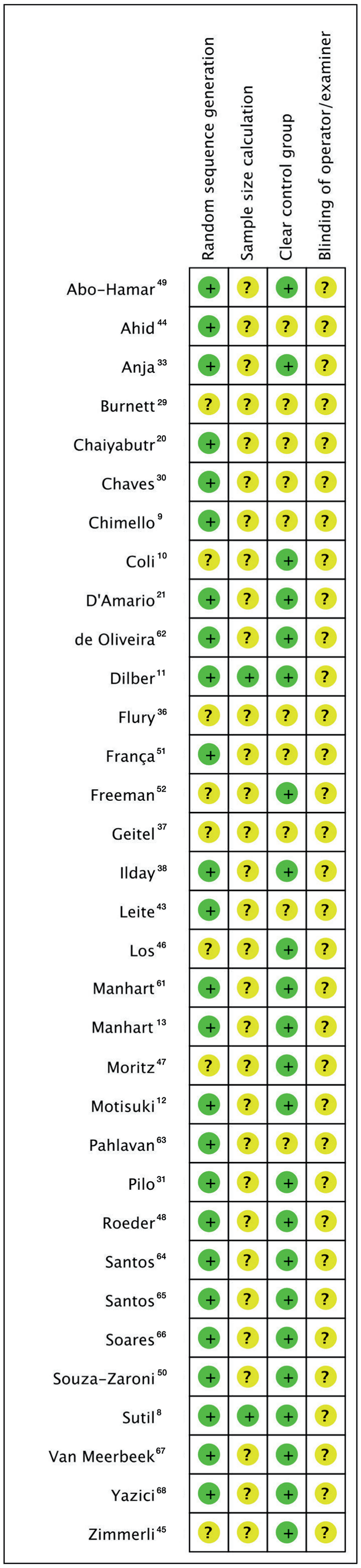


Figure 3. *Risk of bias for each item judged as low, unclear or high in each included study.*

ever, findings of the present investigation suggest that those irregular surface aspects may not negatively interfere with the bonding of resin-based materials to dentin. In fact, increasing dentin surface roughness and producing a more irregular surface texture are the goals of APA in many clinical cases. Propelling aluminum oxide particles to dentin may result in substance removal from the surface because of the kinetic energy of the accelerated particles and differences in hardness between the abrasive and the dentin tissue. Aluminum oxide particles have a Vickers hardness of approximately 1200 kg/mm^2, whereas the Vickers hardness of dentin is approximately 57-60 kg/mm^2.[60] The rougher dentin surfaces may improve micromechanical interlocking between adhesive agents and restorative materials or improve the wettability of dentin surfaces. This may explain the findings showing that APA was able to improve the dentin bond strength, although only in a few cases and only in the short term.

The improved bond strength to air-abraded dentin was dependent on particle size and pressure of the air stream used.[20,47,61] Aluminum oxide particles >30 μm in size generally yielded better bond strength, although the same effect was observed for particles ≤ 30 μm when the control was bur. Application of any particle size could potentially increase surface roughness and, thus, the interaction of adhesive agents with dentin. The differences observed for the distinct particle sizes could be explained by their distinct ability in generating morphologic changes for micromechanical keying on dentin surfaces. In addition, air pressures >5 bar, which are in the range of air pressures produced by dental turbines, also led to improved dentin bond strength in a few cases, whereas lower pressures did not yield the same result. In contrast, APA duration was not particularly important for the bond strength to dentin. Therefore, it appears reasonable to suggest that in cases of use of APA in dentin as surface pretreatment seeking for improved bonding,[23–25] aluminum oxide particle sizes >30 μm and air pressure >5 bar should be preferred, although further analyses in this regard are warranted. In case the dentist intends to apply APA to the dentin for other clinical purposes, such as surface cleaning, any particle size or air pressure could be used. It should be highlighted, however, that the actual ability of APA in cleaning the dentin was not investigated here.

Variability in methods used among studies for air-abrading the dentin surfaces was observed,

Study or Subgroup	Air abrasion Mean	Air abrasion SD	Air abrasion Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.1.1 Control: No treatment								
Abo-Hamar[49]	26.67	8.17	10	29.1	9.6	10	12.6%	-0.26 [-1.14, 0.62]
Abo-Hamar[49]	12.13	4.07	10	13.8	4.16	10	12.5%	-0.39 [-1.28, 0.50]
Dilber[11]	2.46	1.11	15	2.01	1.51	15	15.3%	0.33 [-0.39, 1.05]
Flury[36]	15.2	4.6	15	11.85	4.8	15	15.0%	0.69 [-0.05, 1.43]
Flury[36]	13.73	4.1	15	7.13	6.2	15	14.1%	1.22 [0.43, 2.01]
Freeman[52]	15.05	3.93	8	17.5	5.36	8	10.9%	-0.49 [-1.49, 0.51]
Moritz[47]	5.84	11.21	60	1.5	0.44	20	19.7%	0.44 [-0.07, 0.95]
Subtotal (95% CI)			**133**			**93**	**100.0%**	**0.28 [-0.15, 0.70]**
Heterogeneity: Tau² = 0.17; Chi² = 12.87, df = 6 (P = 0.05); I² = 53%								
Test for overall effect: Z = 1.29 (P = 0.20)								
1.1.2 Control: Hand excavator								
Chaiyabutr[20]	8.54	6.4	16	3.86	1.15	8	51.5%	0.85 [-0.04, 1.74]
Santos[64]	11.3	1.7	13	7.74	1.72	13	48.5%	2.02 [1.04, 2.99]
Subtotal (95% CI)			**29**			**21**	**100.0%**	**1.42 [0.27, 2.56]**
Heterogeneity: Tau² = 0.46; Chi² = 3.02, df = 1 (P = 0.08); I² = 67%								
Test for overall effect: Z = 2.43 (P = 0.02)								
1.1.3 Control: SiC paper								
Anja[33]	35.8	13.5	84	35.3	12.8	64	4.2%	0.04 [-0.29, 0.36]
Chaves[30]	11.4	3.6	3	12.8	4.2	3	2.1%	-0.29 [-1.91, 1.34]
Chaves[30]	25.7	4.1	3	21.1	4.3	3	1.9%	0.88 [-0.93, 2.69]
Chaves[30]	38.6	12.3	3	40.2	6.1	3	2.1%	-0.13 [-1.74, 1.47]
Coli[10]	6.05	3.62	15	8.39	4.6	15	3.6%	-0.55 [-1.28, 0.18]
Coli[10]	4.1	1.54	15	6.09	4.34	15	3.6%	-0.59 [-1.33, 0.14]
D'Amario[21]	28.73	7.06	5	14.47	5.75	5	2.0%	2.00 [0.33, 3.68]
D'Amario[21]	35.51	8.41	5	18.31	6.72	5	2.0%	2.04 [0.35, 3.73]
D'Amario[21]	32.6	7.31	5	16.49	4.61	5	1.8%	2.38 [0.56, 4.21]
D'Amario[21]	33.36	9.98	5	27.68	4.98	5	2.6%	0.65 [-0.64, 1.94]
de Oliveira[62]	30.1	8.6	6	20.4	6.4	6	2.6%	1.18 [-0.09, 2.45]
de Oliveira[62]	28.5	1.3	6	33.9	4.7	6	2.5%	-1.45 [-2.78, -0.11]
de Oliveira[62]	21.2	2.7	6	29.9	4.5	6	2.2%	-2.16 [-3.71, -0.62]
de Oliveira[62]	33	5	6	41.5	2.9	6	2.3%	-1.92 [-3.39, -0.45]
França[51]	27	7.2	36	31.8	7.5	41	4.1%	-0.65 [-1.11, -0.19]
França[51]	28.2	8.3	36	29.4	7.9	36	4.1%	-0.15 [-0.61, 0.32]
Ilday[38]	16.55	6.47	16	13.81	6.05	8	3.4%	0.42 [-0.44, 1.28]
Ilday[38]	17.12	7.12	16	11.96	5.37	8	3.3%	0.75 [-0.13, 1.63]
Los[46]	20.7	1.6	10	20.4	2	10	3.3%	0.16 [-0.72, 1.04]
Los[46]	19.3	2.6	10	15.7	3.8	10	3.2%	1.06 [0.11, 2.01]
Los[46]	17.1	1.2	10	18.2	1.6	10	3.3%	-0.74 [-1.66, 0.17]
Manhart[61]	23	2.6	10	20.2	1.9	10	3.2%	1.18 [0.21, 2.14]
Manhart[61]	15.4	3.6	10	16.4	4.6	10	3.3%	-0.23 [-1.11, 0.65]
Manhart[13]	19.95	11.5	40	15.4	2.1	20	3.9%	0.47 [-0.07, 1.02]
Manhart[13]	16.35	7.24	40	8.3	4.7	20	3.9%	1.22 [0.64, 1.80]
Roeder[48]	21	9.4	20	24.1	8	10	3.5%	-0.34 [-1.10, 0.43]
Santos[65]	14.21	4.88	12	11.74	4.01	12	3.4%	0.53 [-0.28, 1.35]
Santos[65]	11.03	4.15	12	13.83	6.44	12	3.5%	-0.50 [-1.31, 0.32]
Santos[65]	22.68	9.55	12	17.24	7.03	12	3.4%	0.63 [-0.20, 1.45]
Soares[66]	16.67	2.37	10	26.82	4.55	10	2.6%	-2.68 [-3.96, -1.40]
Soares[66]	13.5	2.3	10	22.08	2.41	10	2.3%	-3.49 [-4.98, -2.00]
Sutil[8]	52.38	11	16	32.92	6.19	8	3.0%	1.93 [0.89, 2.97]
Yazici[68]	14.09	5.94	14	14.44	6.23	14	3.6%	-0.06 [-0.80, 0.69]
Subtotal (95% CI)			**507**			**418**	**100.0%**	**0.05 [-0.28, 0.37]**
Heterogeneity: Tau² = 0.62; Chi² = 148.08, df = 32 (P < 0.00001); I² = 78%								
Test for overall effect: Z = 0.29 (P = 0.78)								
1.1.4 Control: Bur								
Burnett[29]	17.52	2.01	15	15.83	1.51	15	12.5%	0.92 [0.17, 1.68]
Motisuki[12]	53.2	32.46	20	40.34	14.85	10	12.3%	0.45 [-0.32, 1.22]
Pahlavan[63]	14.98	3.98	10	20.86	6.76	10	9.2%	-1.02 [-1.96, -0.07]
Souza-Zaroni[50]	31.7	8.1	20	28.51	6.29	20	15.8%	0.43 [-0.20, 1.06]
Van Meerbeek[67]	54.1	13	3	37.7	10.5	3	2.7%	1.11 [-0.82, 3.04]
Van Meerbeek[67]	54.9	16.3	3	59.6	16.8	3	3.7%	-0.23 [-1.84, 1.39]
Van Meerbeek[67]	24.6	17.6	3	27.3	13.6	3	3.8%	-0.14 [-1.74, 1.47]
Zimmerli[45]	42.5	10.5	31	38.8	12.1	31	20.0%	0.32 [-0.18, 0.82]
Zimmerli[45]	39.5	11.6	31	34.6	11.8	31	19.9%	0.41 [-0.09, 0.92]
Subtotal (95% CI)			**136**			**126**	**100.0%**	**0.31 [-0.02, 0.64]**
Heterogeneity: Tau² = 0.08; Chi² = 11.87, df = 8 (P = 0.16); I² = 33%								
Test for overall effect: Z = 1.84 (P = 0.07)								
1.1.5 Control: Acid etching								
Ahid[44]	41	9.3	5	29.2	8.3	5	3.6%	1.21 [-0.21, 2.62]
Ahid[44]	48.1	14.2	5	43	16.1	5	4.4%	0.30 [-0.95, 1.55]
Chimello[9]	16.47	4.73	5	16.93	2.56	5	4.4%	-0.11 [-1.35, 1.13]
Chimello[9]	18.21	5.61	5	9.61	2.96	5	3.0%	1.73 [0.15, 3.31]
Dilber[11]	4.53	1.23	15	4.61	1.47	15	9.7%	-0.06 [-0.77, 0.66]
Flury[36]	19.23	5.8	15	15.78	4.7	15	9.3%	0.64 [-0.10, 1.37]
Freeman[52]	17.96	5.99	8	16.15	4.64	8	6.3%	0.32 [-0.67, 1.31]
Geitel[37]	8.68	17.06	80	12.76	3.8	20	14.0%	-0.26 [-0.75, 0.23]
Geitel[37]	3.91	13.53	80	8.1	4.36	20	14.0%	-0.34 [-0.83, 0.15]
Manhart[13]	19.95	11.5	40	15.4	2.1	20	12.8%	0.47 [-0.07, 1.02]
Pilo[31]	9.94	6.05	15	9.97	6.97	15	9.7%	-0.00 [-0.72, 0.71]
Pilo[31]	9.54	4.93	14	11.8	4.34	13	8.9%	-0.47 [-1.24, 0.30]
Subtotal (95% CI)			**287**			**146**	**100.0%**	**0.11 [-0.18, 0.40]**
Heterogeneity: Tau² = 0.09; Chi² = 18.03, df = 11 (P = 0.08); I² = 39%								
Test for overall effect: Z = 0.75 (P = 0.45)								
Test for subgroup differences: Chi² = 6.10, df = 4 (P = 0.19), I² = 34.4%								

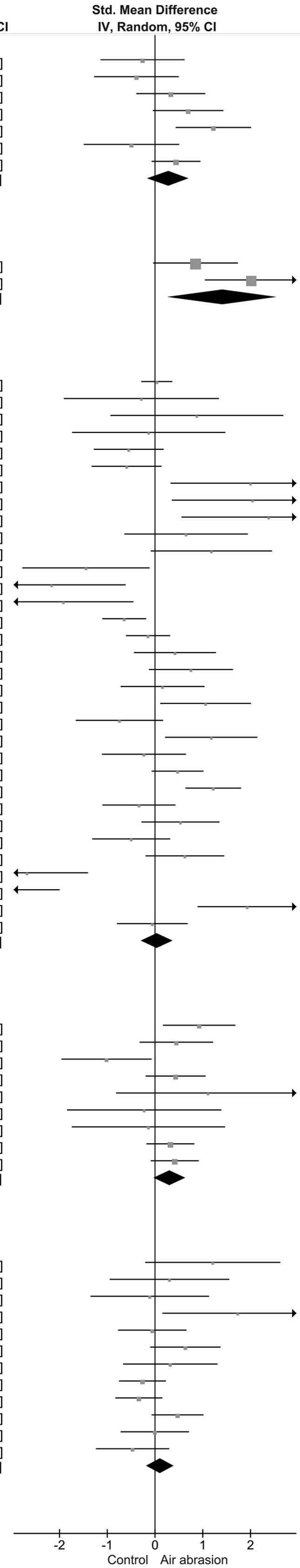


Figure 4. *Meta-analysis on dentin bond strength values considering the different combinations of intervention-control comparisons. Statistically significant difference was observed when the control surface was treated with a hand excavator (*p=0.02*).*

Study or Subgroup	Air abrasion Mean	Air abrasion SD	Air abrasion Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.1.1 Control: No treatment (Particle size ≤ 30 μm)								
Abo-Hamar [49]	12.13	4.07	10	13.8	4.16	10	33.1%	-0.39 [-1.28, 0.50]
Abo-Hamar [49]	26.67	8.17	10	29.1	9.6	10	33.1%	-0.26 [-1.14, 0.62]
Moritz [47]	4.74	2.1	20	1.5	0.44	20	33.8%	2.09 [1.31, 2.88]
Subtotal (95% CI)			**40**			**40**	**100.0%**	**0.49 [-1.15, 2.13]**
Heterogeneity: Tau² = 1.91; Chi² = 22.31, df = 2 (P < 0.0001); I² = 91%								
Test for overall effect: Z = 0.59 (P = 0.56)								
2.1.2 Control: No treatment (Particle size > 30 μm)								
Dilber [11]	2.46	1.11	15	2.01	1.51	15	20.8%	0.33 [-0.39, 1.05]
Flury [36]	13.73	4.1	15	7.13	6.2	15	19.4%	1.22 [0.43, 2.01]
Flury [36]	15.2	4.6	15	11.85	4.8	15	20.4%	0.69 [-0.05, 1.43]
Freeman [52]	15.05	3.93	8	17.5	5.36	8	15.7%	-0.49 [-1.49, 0.51]
Moritz [47]	6.37	4.84	40	1.5	0.44	20	23.7%	1.21 [0.63, 1.79]
Subtotal (95% CI)			**93**			**73**	**100.0%**	**0.66 [0.10, 1.21]**
Heterogeneity: Tau² = 0.25; Chi² = 11.03, df = 4 (P = 0.03); I² = 64%								
Test for overall effect: Z = 2.31 (P = 0.02)								
2.1.3 Control: Hand excavator (Particle size > 30 μm)								
Chaiyabutr [20]	8.47	3.34	8	3.86	1.15	8	39.5%	1.74 [0.54, 2.95]
Santos [64]	11.3	1.7	13	7.74	1.72	13	60.5%	2.02 [1.04, 2.99]
Subtotal (95% CI)			**21**			**21**	**100.0%**	**1.91 [1.15, 2.66]**
Heterogeneity: Tau² = 0.00; Chi² = 0.12, df = 1 (P = 0.73); I² = 0%								
Test for overall effect: Z = 4.95 (P < 0.00001)								
2.1.4 Control: Sic Paper (Particle size ≤ 30 μm)								
de Oliveira [62]	21.2	2.7	6	29.9	4.5	6	10.3%	-2.16 [-3.71, -0.62]
de Oliveira [62]	33	5	6	41.5	2.9	6	10.7%	-1.92 [-3.39, -0.45]
de Oliveira [62]	30.1	0.6	6	20.4	6.4	6	10.6%	1.97 [0.48, 3.45]
de Oliveira [62]	28.5	1.3	6	33.9	4.7	6	11.5%	-1.45 [-2.78, -0.11]
Ilday [38]	15.65	4.34	8	13.81	6.05	8	13.7%	0.33 [-0.66, 1.32]
Ilday [38]	14.38	3.48	8	11.96	5.37	8	13.6%	0.51 [-0.49, 1.51]
Roeder [48]	21.8	7	10	24.1	8	10	14.4%	-0.29 [-1.18, 0.59]
Yazici [68]	14.09	5.94	14	14.44	6.23	14	15.2%	-0.06 [-0.80, 0.69]
Subtotal (95% CI)			**64**			**64**	**100.0%**	**-0.32 [-1.08, 0.44]**
Heterogeneity: Tau² = 0.85; Chi² = 26.20, df = 7 (P = 0.0005); I² = 73%								
Test for overall effect: Z = 0.83 (P = 0.41)								
2.1.5 Control: Sic Paper (Particle size > 30 μm)								
Anja [33]	35.8	13.5	84	35.3	12.8	64	4.6%	0.04 [-0.29, 0.36]
Chaves [30]	38.6	12.3	3	40.2	6.1	3	2.0%	-0.13 [-1.74, 1.47]
Chaves [30]	25.7	4.1	3	21.1	4.3	3	1.7%	0.88 [-0.93, 2.69]
Chaves [30]	11.4	3.6	3	12.8	4.2	3	1.9%	-0.29 [-1.91, 1.34]
Coli [10]	4.1	1.54	15	6.09	4.34	15	3.7%	-0.59 [-1.33, 0.14]
Coli [10]	6.05	3.62	15	4.1	1.54	15	3.7%	0.68 [-0.06, 1.42]
D'Amario [21]	35.51	8.41	5	18.31	6.72	5	1.8%	2.04 [0.35, 3.73]
D'Amario [21]	32.6	7.31	5	16.49	4.61	5	1.7%	2.38 [0.56, 4.21]
D'Amario [21]	33.36	9.98	5	27.68	4.98	5	2.5%	0.65 [-0.64, 1.94]
D'Amario [21]	28.73	7.06	5	14.47	5.75	5	1.9%	2.00 [0.33, 3.68]
França [51]	21	6	38	17.8	6.8	37	4.4%	0.49 [0.03, 0.95]
França [51]	26.9	8.4	40	24.2	8.7	42	4.4%	0.31 [-0.12, 0.75]
França [51]	27	7.2	36	31.8	7.5	41	4.4%	-0.65 [-1.11, -0.19]
França [51]	28.2	8.3	36	29.4	7.9	36	4.4%	-0.15 [-0.61, 0.32]
França [51]	26.7	9.4	39	19.8	10.6	40	4.4%	0.68 [0.23, 1.14]
França [51]	20.7	7.5	36	19.9	6.2	35	4.4%	0.11 [-0.35, 0.58]
Ilday [38]	17.45	2.8	8	13.81	6.05	8	3.1%	0.73 [-0.29, 1.75]
Ilday [38]	15.65	4.34	8	11.96	5.37	8	3.1%	0.71 [-0.31, 1.74]
Los [46]	20.7	1.6	10	20.4	2	10	3.4%	0.16 [-0.72, 1.04]
Los [46]	17.1	1.2	10	18.2	1.6	10	3.3%	-0.74 [-1.66, 0.17]
Los [46]	19.3	2.6	10	15.7	3.8	10	3.2%	1.06 [0.11, 2.01]
Manhart [61]	15.4	3.6	10	16.4	4.6	10	3.4%	-0.23 [-1.11, 0.65]
Manhart [61]	23	2.6	10	20.2	1.9	10	3.2%	1.18 [0.21, 2.14]
Manhart [13]	16.35	7.24	40	8.3	4.7	20	4.1%	1.22 [0.64, 1.80]
Roeder [48]	20.2	3	10	24.1	8	10	3.3%	-0.62 [-1.52, 0.28]
Santos [65]	11.03	4.15	12	13.83	6.44	12	3.5%	-0.50 [-1.31, 0.32]
Santos [65]	22.68	9.55	12	17.24	7.03	12	3.5%	0.63 [-0.20, 1.45]
Santos [65]	14.21	4.88	12	11.74	4.01	12	3.5%	0.53 [-0.28, 1.35]
Soares [66]	16.67	2.37	10	26.82	4.55	10	2.5%	-2.68 [-3.96, -1.40]
Soares [66]	13.5	2.3	10	22.08	2.41	10	2.1%	-3.49 [-4.98, -2.00]
Sutil [8]	52.38	11	16	32.92	6.19	8	3.0%	1.93 [0.89, 2.97]
Subtotal (95% CI)			**556**			**514**	**100.0%**	**0.24 [-0.06, 0.53]**
Heterogeneity: Tau² = 0.45; Chi² = 131.82, df = 30 (P < 0.00001); I² = 77%								
Test for overall effect: Z = 1.59 (P = 0.11)								
2.1.6 Control: Bur (Particle size ≤ 30 μm)								
Burnett [29]	17.52	2.01	15	15.83	1.51	15	12.1%	0.92 [0.17, 1.68]
Motisuki [12]	56.44	18.1	10	40.34	14.85	10	8.0%	0.93 [-0.00, 1.87]
Souza-Zaroni [50]	31.7	8.1	20	28.51	6.29	20	17.6%	0.43 [-0.20, 1.06]
Van Meerbeek [67]	24.6	17.6	3	27.3	13.6	3	2.7%	-0.14 [-1.74, 1.47]
Van Meerbeek [67]	54.1	13	3	37.7	10.5	3	1.9%	1.11 [-0.82, 3.04]
Van Meerbeek [67]	54.9	16.3	3	59.6	16.8	3	2.7%	-0.23 [-1.84, 1.39]
Zimmerli [45]	39.5	11.6	31	34.6	11.8	31	27.4%	0.41 [-0.09, 0.92]
Zimmerli [45]	42.5	10.5	31	38.8	12.1	31	27.7%	0.32 [-0.18, 0.82]
Subtotal (95% CI)			**116**			**116**	**100.0%**	**0.48 [0.21, 0.74]**
Heterogeneity: Tau² = 0.00; Chi² = 4.40, df = 7 (P = 0.73); I² = 0%								
Test for overall effect: Z = 3.54 (P = 0.0004)								
2.1.7 Control: Bur (Particle size > 30 μm)								
Motisuki [12]	49.95	18.94	10	40.34	14.85	10	50.5%	0.54 [-0.36, 1.44]
Pahlavan [63]	14.98	3.98	10	20.8	6.76	10	49.5%	-1.00 [-1.95, -0.06]
Subtotal (95% CI)			**20**			**20**	**100.0%**	**-0.22 [-1.74, 1.29]**
Heterogeneity: Tau² = 0.97; Chi² = 5.42, df = 1 (P = 0.02); I² = 82%								
Test for overall effect: Z = 0.29 (P = 0.77)								
2.1.8 Control: Acid etching (Particle size ≤ 30 μm)								
Ahid [44]	41	9.3	5	29.2	8.3	5	11.5%	1.21 [-0.21, 2.62]
Ahid [44]	48.1	14.2	5	43	16.1	5	13.4%	0.30 [-0.95, 1.55]
Chimello [9]	16.47	4.73	5	16.93	2.56	5	13.6%	-0.11 [-1.35, 1.13]
Chimello [9]	18.21	5.61	5	9.61	2.96	5	10.0%	1.73 [0.15, 3.31]
Geitel [37]	9.03	7.39	40	12.76	3.8	20	25.7%	-0.57 [-1.12, -0.02]
Geitel [37]	6.66	8.2	40	8.1	4.36	20	25.9%	-0.20 [-0.74, 0.34]
Subtotal (95% CI)			**100**			**60**	**100.0%**	**0.14 [-0.46, 0.74]**
Heterogeneity: Tau² = 0.28; Chi² = 11.83, df = 5 (P = 0.04); I² = 58%								
Test for overall effect: Z = 0.46 (P = 0.65)								
2.1.9 Control: Acid etching (Particle size > 30 μm)								
Chimello [9]	16.47	4.73	5	16.93	2.56	5	7.1%	-0.11 [-1.35, 1.13]
Chimello [9]	18.21	5.61	5	9.61	2.96	5	5.4%	1.73 [0.15, 3.31]
Dilber [11]	3.5	2.76	30	2.01	1.51	15	11.3%	0.60 [-0.03, 1.24]
Flury [36]	19.23	5.8	15	15.78	4.7	15	10.6%	0.64 [-0.10, 1.37]
Freeman [52]	17.96	5.99	8	16.15	4.64	8	8.7%	0.32 [-0.67, 1.31]
Geitel [37]	8.34	4.73	40	12.76	3.8	20	11.8%	-0.98 [-1.55, -0.41]
Geitel [37]	4	5.31	40	8.1	4.36	20	11.9%	-0.81 [-1.36, -0.25]
Manhart [13]	19.95	11.5	40	15.4	2.1	20	12.0%	0.47 [-0.07, 1.02]
Pilo [31]	9.94	6.05	15	9.97	6.97	15	10.7%	-0.00 [-0.72, 0.71]
Pilo [31]	9.54	4.93	14	11.8	4.34	13	10.3%	-0.47 [-1.24, 0.30]
Subtotal (95% CI)			**212**			**136**	**100.0%**	**0.05 [-0.42, 0.51]**
Heterogeneity: Tau² = 0.39; Chi² = 35.03, df = 9 (P < 0.0001); I² = 74%								
Test for overall effect: Z = 0.19 (P = 0.85)								

Test for subgroup differences: Chi² = 24.61, df = 8 (P = 0.002), I² = 67.5%

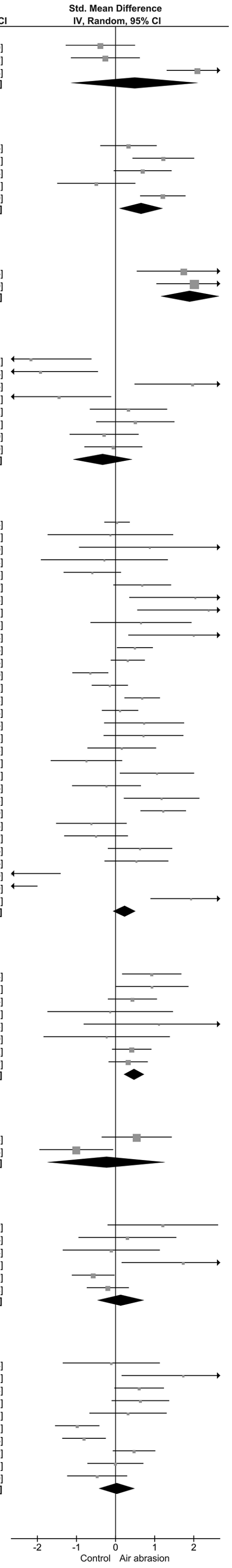
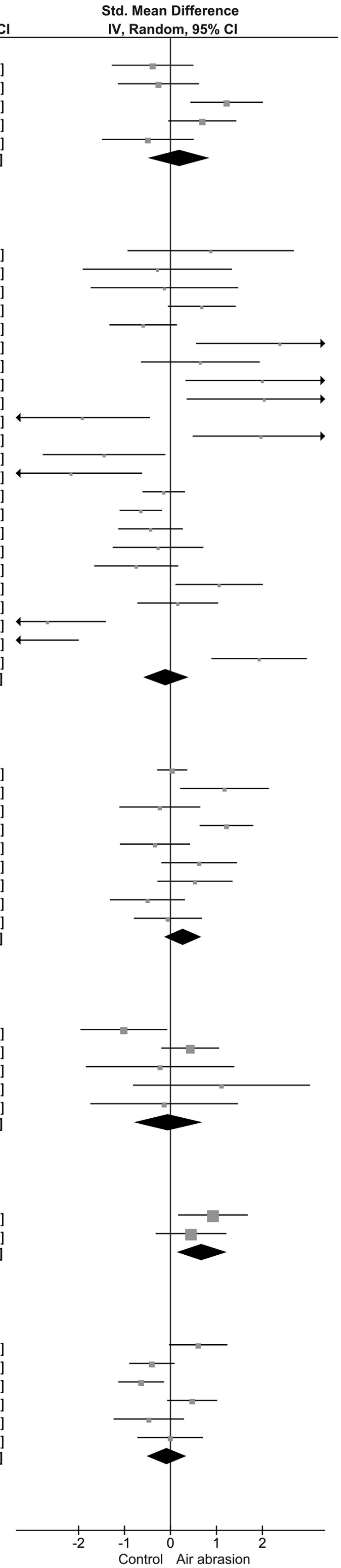


Figure 5. *Meta-analysis for particle size (≤30 μm or >30 μm) with same intervention-control groups. Statistically significant differences were observed when the particle size was >30 μm and the controls were no treatment (*p=0.02*) or hand excavator (*p<0.00001*). Considering particle size ≤30 μm, a statistically significant difference was observed when the control was bur (*p=0.0004*).*

Study or Subgroup	Air abrasion Mean	Air abrasion SD	Air abrasion Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.1.1 Control: No treatment (Air pressure ≤ 5 bar)								
Abo-Hamar[49]	12.13	4.07	10	13.8	4.16	10	19.6%	-0.39 [-1.28, 0.50]
Abo-Hamar[49]	26.67	8.17	10	29.1	9.6	10	19.7%	-0.26 [-1.14, 0.62]
Flury[36]	13.73	4.1	15	7.13	6.2	15	21.0%	1.22 [0.43, 2.01]
Flury[36]	15.2	4.6	15	11.85	4.8	15	21.8%	0.69 [-0.05, 1.43]
Freeman[52]	15.05	3.93	8	17.5	5.36	8	17.9%	-0.49 [-1.49, 0.51]
Subtotal (95% CI)			**58**			**58**	**100.0%**	**0.19 [-0.48, 0.87]**
Heterogeneity: Tau² = 0.40; Chi² = 12.60, df = 4 (P = 0.01); I² = 68%								
Test for overall effect: Z = 0.56 (P = 0.58)								
3.1.2 Control: Sic paper (Air pressure ≤ 5 bar)								
Chaves[30]	25.7	4.1	3	21.1	4.3	3	3.3%	0.88 [-0.93, 2.69]
Chaves[30]	11.4	3.6	3	12.8	4.2	3	3.6%	-0.29 [-1.91, 1.34]
Chaves[30]	38.6	12.3	3	40.2	6.1	3	3.6%	-0.13 [-1.74, 1.47]
Coli[10]	6.05	3.62	15	4.1	1.54	15	5.3%	0.68 [-0.06, 1.42]
Coli[10]	4.1	1.54	15	6.09	4.34	15	5.3%	-0.59 [-1.33, 0.14]
D'Amario[21]	32.6	7.31	5	16.49	4.61	5	3.2%	2.38 [0.56, 4.21]
D'Amario[21]	33.36	9.98	5	27.68	4.98	5	4.2%	0.65 [-0.64, 1.94]
D'Amario[21]	28.73	7.06	5	14.47	5.75	5	3.5%	2.00 [0.33, 3.68]
D'Amario[21]	35.51	8.41	5	18.31	6.72	5	3.5%	2.04 [0.35, 3.73]
de Oliveira[62]	33	5	6	41.5	2.9	6	3.9%	-1.92 [-3.39, -0.45]
de Oliveira[62]	30.1	0.6	6	20.4	6.4	6	3.8%	1.97 [0.48, 3.45]
de Oliveira[62]	28.5	1.3	6	33.9	4.7	6	4.1%	-1.45 [-2.78, -0.11]
de Oliveira[62]	21.2	2.7	6	29.9	4.5	6	3.7%	-2.16 [-3.71, -0.62]
França[51]	28.2	8.3	36	29.4	7.9	36	5.7%	-0.15 [-0.61, 0.32]
França[51]	27	7.2	36	31.8	7.5	41	5.7%	-0.65 [-1.11, -0.19]
Ilday[38]	15.02	6.84	16	19.05	10.83	16	5.3%	-0.43 [-1.14, 0.27]
Ilday[38]	19.85	2.31	8	21.22	6.39	8	4.8%	-0.27 [-1.26, 0.72]
Los[46]	17.1	1.2	10	18.2	1.6	10	4.9%	-0.74 [-1.66, 0.17]
Los[46]	19.3	2.6	10	15.7	3.8	10	4.9%	1.06 [0.11, 2.01]
Los[46]	20.7	1.6	10	20.4	2	10	5.0%	0.16 [-0.72, 1.04]
Soares[66]	16.67	2.37	10	26.82	4.55	10	4.2%	-2.68 [-3.96, -1.40]
Soares[66]	13.5	2.3	10	22.08	2.41	10	3.8%	-3.49 [-4.98, -2.00]
Sutil[8]	52.38	11	16	32.92	6.19	8	4.7%	1.93 [0.89, 2.97]
Subtotal (95% CI)			**245**			**242**	**100.0%**	**-0.09 [-0.58, 0.40]**
Heterogeneity: Tau² = 1.02; Chi² = 115.89, df = 22 (P < 0.00001); I² = 81%								
Test for overall effect: Z = 0.36 (P = 0.72)								
3.1.3 Control: SiC paper (Air pressure > 5 bar)								
Anja[33]	35.8	13.5	84	35.3	12.8	64	15.9%	0.04 [-0.29, 0.36]
Manhart[61]	23	2.6	10	20.2	1.9	10	8.8%	1.18 [0.21, 2.14]
Manhart[61]	15.4	3.6	10	16.4	4.6	10	9.6%	-0.23 [-1.11, 0.65]
Manhart[13]	16.35	7.24	40	8.3	4.7	20	13.0%	1.22 [0.64, 1.80]
Roeder[48]	21	9.4	20	24.1	8	10	10.8%	-0.34 [-1.10, 0.43]
Santos[65]	22.68	9.55	12	17.24	7.03	12	10.2%	0.63 [-0.20, 1.45]
Santos[65]	14.21	4.88	12	11.74	4.01	12	10.3%	0.53 [-0.28, 1.35]
Santos[65]	11.03	4.15	12	13.83	6.44	12	10.3%	-0.50 [-1.31, 0.32]
Yazici[68]	14.09	5.94	14	14.44	6.23	14	11.1%	-0.06 [-0.80, 0.69]
Subtotal (95% CI)			**214**			**164**	**100.0%**	**0.27 [-0.13, 0.67]**
Heterogeneity: Tau² = 0.24; Chi² = 24.35, df = 8 (P = 0.002); I² = 67%								
Test for overall effect: Z = 1.31 (P = 0.19)								
3.1.4 Control: Bur (Air pressure ≤ 5 bar)								
Pahlavan[63]	14.98	3.98	10	20.86	6.76	10	26.0%	-1.02 [-1.96, -0.07]
Souza-Zaroni[50]	31.7	8.1	20	28.51	6.29	20	34.1%	0.43 [-0.20, 1.06]
Van Meerbeek[67]	54.9	16.3	3	59.6	16.8	3	14.3%	-0.23 [-1.84, 1.39]
Van Meerbeek[67]	54.1	13	3	37.7	10.5	3	11.1%	1.11 [-0.82, 3.04]
Van Meerbeek[67]	24.6	17.6	3	27.3	13.6	3	14.4%	-0.14 [-1.74, 1.47]
Subtotal (95% CI)			**39**			**39**	**100.0%**	**-0.05 [-0.79, 0.69]**
Heterogeneity: Tau² = 0.32; Chi² = 7.62, df = 4 (P = 0.11); I² = 48%								
Test for overall effect: Z = 0.12 (P = 0.90)								
3.1.5 Control: Bur (Air pressure > 5 bar)								
Burnett[29]	17.52	2.01	15	15.83	1.51	15	50.7%	0.92 [0.17, 1.68]
Motisuki[12]	53.2	32.46	20	40.34	14.85	10	49.3%	0.45 [-0.32, 1.22]
Subtotal (95% CI)			**35**			**25**	**100.0%**	**0.69 [0.15, 1.23]**
Heterogeneity: Tau² = 0.00; Chi² = 0.75, df = 1 (P = 0.38); I² = 0%								
Test for overall effect: Z = 2.50 (P = 0.01)								
3.1.6 Control: Acid etching (Air pressure > 5 bar)								
Dilber[11]	3.5	2.76	30	2.01	1.51	15	16.2%	0.60 [-0.03, 1.24]
Geitel[37]	8.69	10.98	80	12.76	3.8	20	18.7%	-0.40 [-0.90, 0.09]
Geitel[37]	4.61	5.66	80	8.1	4.36	20	18.6%	-0.64 [-1.14, -0.14]
Manhart[13]	19.95	11.5	40	15.4	2.1	20	17.8%	0.47 [-0.07, 1.02]
Pilo[31]	9.54	4.93	14	11.8	4.34	13	13.9%	-0.47 [-1.24, 0.30]
Pilo[31]	9.94	6.05	15	9.97	6.97	15	14.8%	-0.00 [-0.72, 0.71]
Subtotal (95% CI)			**259**			**103**	**100.0%**	**-0.08 [-0.51, 0.35]**
Heterogeneity: Tau² = 0.20; Chi² = 15.89, df = 5 (P = 0.007); I² = 69%								
Test for overall effect: Z = 0.36 (P = 0.72)								



Test for subgroup differences: Chi² = 6.47, df = 5 (P = 0.26), I² = 22.7%

Figure 6. *Meta-analysis for air pressure (≤5 bar or >5 bar) with same intervention-control groups. Statistically significant difference was observed when the air pressure was >5 bar and bur was used to treat the control surfaces (*p*=0.01).*

Study or Subgroup	Air abrasion Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
4.1.1 Control: No treatment (Air abrasion duration ≤ 10s)								
Dilber[11]	2.46	1.11	15	2.01	1.51	15	27.2%	0.33 [-0.39, 1.05]
Flury[36]	13.73	4.1	15	7.13	6.2	15	25.5%	1.22 [0.43, 2.01]
Flury[36]	15.2	4.6	15	11.85	4.8	15	26.7%	0.69 [-0.05, 1.43]
Freeman[52]	15.05	3.93	8	17.5	5.36	8	20.6%	-0.49 [-1.49, 0.51]
Subtotal (95% CI)			**53**			**53**	**100.0%**	**0.49 [-0.15, 1.12]**
Heterogeneity: Tau² = 0.25; Chi² = 7.46, df = 3 (P = 0.06); I² = 60%								
Test for overall effect: Z = 1.50 (P = 0.13)								
4.1.2 Control: SiC paper (Air abrasion duration ≤ 10s)								
Chaves[30]	38.6	12.3	3	40.2	6.1	3	3.7%	-0.13 [-1.74, 1.47]
Chaves[30]	25.7	4.1	3	21.1	4.3	3	3.3%	0.88 [-0.93, 2.69]
Chaves[30]	11.4	3.6	3	12.8	4.2	3	3.7%	-0.29 [-1.91, 1.34]
D'Amario[21]	33.36	9.98	5	27.68	4.98	5	4.4%	0.65 [-0.64, 1.94]
D'Amario[21]	35.51	8.41	5	18.31	6.72	5	3.5%	2.04 [0.35, 3.73]
D'Amario[21]	32.6	7.31	5	16.49	4.61	5	3.3%	2.38 [0.56, 4.21]
D'Amario[21]	28.73	7.06	5	14.47	5.75	5	3.6%	2.00 [0.33, 3.68]
França[51]	27	7.2	36	31.8	7.5	41	6.1%	-0.65 [-1.11, -0.19]
França[51]	28.2	8.3	36	29.4	7.9	36	6.1%	-0.15 [-0.61, 0.32]
Ilday[38]	17.12	7.12	16	11.96	5.37	8	5.3%	0.75 [-0.13, 1.63]
Ilday[38]	16.55	6.47	16	13.81	6.05	8	5.4%	0.42 [-0.44, 1.28]
Manhart[61]	23	2.6	10	20.2	1.9	10	5.1%	1.18 [0.21, 2.14]
Manhart[61]	15.4	3.6	10	16.4	4.6	10	5.3%	-0.23 [-1.11, 0.65]
Manhart[13]	16.35	7.24	40	8.3	4.7	20	5.9%	1.22 [0.64, 1.80]
Santos[65]	22.68	9.55	12	17.24	7.03	12	5.4%	0.63 [-0.20, 1.45]
Santos[65]	14.21	4.88	12	11.74	4.01	12	5.4%	0.53 [-0.28, 1.35]
Santos[65]	11.03	4.15	12	13.83	6.44	12	5.5%	-0.50 [-1.31, 0.32]
Soares[66]	13.5	2.3	10	22.08	2.41	10	3.9%	-3.49 [-4.98, -2.00]
Soares[66]	16.67	2.37	10	26.82	4.55	10	4.4%	-2.68 [-3.96, -1.40]
Sutil[8]	52.38	11	16	32.92	6.19	8	4.9%	1.93 [0.89, 2.97]
Yazici[68]	14.09	5.94	14	14.44	6.23	14	5.6%	-0.06 [-0.80, 0.69]
Subtotal (95% CI)			**279**			**240**	**100.0%**	**0.27 [-0.20, 0.74]**
Heterogeneity: Tau² = 0.89; Chi² = 108.04, df = 20 (P < 0.00001); I² = 81%								
Test for overall effect: Z = 1.13 (P = 0.26)								
4.1.3 Control: Acid etching (Air abrasion duration ≤ 10s)								
Ahid[44]	48.1	14.2	5	43	16.1	5	4.7%	0.30 [-0.95, 1.55]
Ahid[44]	41	9.3	5	29.2	8.3	5	3.9%	1.21 [-0.21, 2.62]
Dilber[11]	3.5	2.76	30	2.01	1.51	15	11.8%	0.60 [-0.03, 1.24]
Flury[36]	19.23	5.8	15	15.78	4.7	15	10.0%	0.64 [-0.10, 1.37]
Freeman[52]	17.96	5.99	8	16.15	4.64	8	6.8%	0.32 [-0.67, 1.31]
Geitel[37]	3.91	13.53	80	8.1	4.36	20	14.7%	-0.34 [-0.83, 0.15]
Geitel[37]	8.68	17.06	80	12.76	3.8	20	14.8%	-0.26 [-0.75, 0.23]
Manhart[13]	19.95	11.5	40	15.4	2.1	20	13.6%	0.47 [-0.07, 1.02]
Pilo[31]	9.54	4.93	14	11.8	4.34	13	9.5%	-0.47 [-1.24, 0.30]
Pilo[31]	9.94	6.05	15	9.97	6.97	15	10.3%	-0.00 [-0.72, 0.71]
Subtotal (95% CI)			**292**			**136**	**100.0%**	**0.15 [-0.16, 0.45]**
Heterogeneity: Tau² = 0.10; Chi² = 16.26, df = 9 (P = 0.06); I² = 45%								
Test for overall effect: Z = 0.95 (P = 0.34)								
4.1.4 Control: SiC paper (Air abrasion duration ≥ 15s)								
Anja[33]	35.8	13.5	84	35.3	12.8	64	17.7%	0.04 [-0.29, 0.36]
Coli[10]	6.05	3.62	15	4.1	1.54	15	15.0%	0.68 [-0.06, 1.42]
Coli[10]	8.39	4.6	15	6.09	4.34	15	15.1%	0.50 [-0.23, 1.23]
de Oliveira[62]	33	5	6	41.5	2.9	6	9.7%	-1.92 [-3.39, -0.45]
de Oliveira[62]	30.1	0.6	6	20.4	6.4	6	9.6%	1.97 [0.48, 3.45]
de Oliveira[62]	28.5	1.3	6	33.9	4.7	6	10.6%	-1.45 [-2.78, -0.11]
de Oliveira[62]	21.2	2.7	6	29.9	4.5	6	9.2%	-2.16 [-3.71, -0.62]
Ilday[38]	19.85	2.31	8	21.22	6.39	8	13.1%	-0.27 [-1.26, 0.72]
Subtotal (95% CI)			**146**			**126**	**100.0%**	**-0.20 [-0.86, 0.46]**
Heterogeneity: Tau² = 0.62; Chi² = 30.69, df = 7 (P < 0.0001); I² = 77%								
Test for overall effect: Z = 0.59 (P = 0.55)								
4.1.5 Control: Bur (Air abrasion duration ≥ 15s)								
Motisuki[12]	53.2	32.46	20	40.34	14.85	10	21.9%	0.45 [-0.32, 1.22]
Pahlavan[63]	14.98	3.98	10	20.86	6.76	10	17.5%	-1.02 [-1.96, -0.07]
Zimmerli[45]	39.5	11.6	31	34.6	11.8	31	30.3%	0.41 [-0.09, 0.92]
Zimmerli[45]	42.5	10.5	31	38.8	12.1	31	30.4%	0.32 [-0.18, 0.82]
Subtotal (95% CI)			**92**			**82**	**100.0%**	**0.14 [-0.37, 0.66]**
Heterogeneity: Tau² = 0.16; Chi² = 7.63, df = 3 (P = 0.05); I² = 61%								
Test for overall effect: Z = 0.54 (P = 0.59)								
Test for subgroup differences: Chi² = 2.36, df = 4 (P = 0.67), I² = 0%								

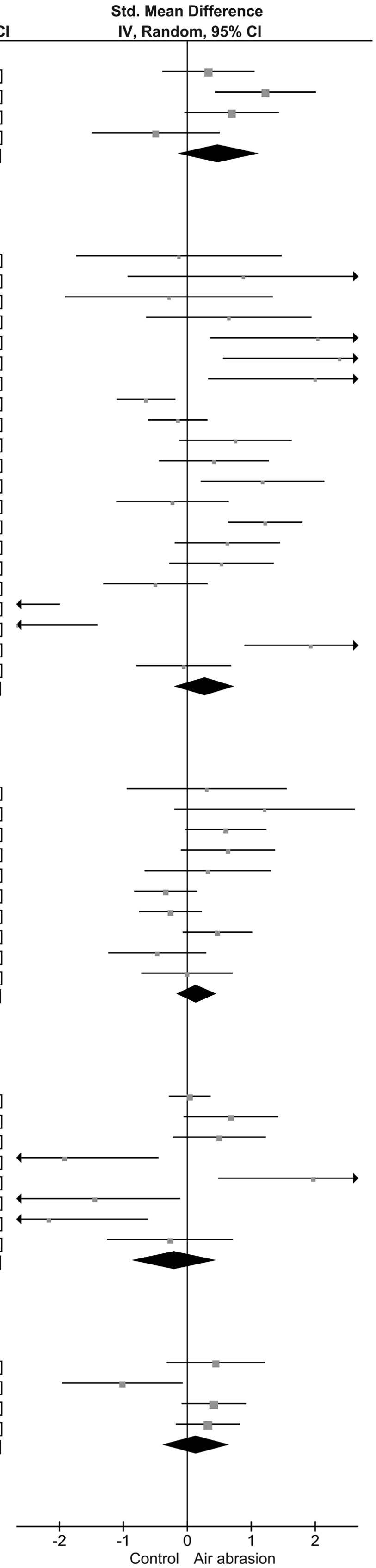


Figure 7. *Meta-analysis for airborne-particle abrasion duration (≤10 seconds or ≥15 seconds) with same intervention-control groups. No significant differences were observed in bond strength between control and air-abraded dentin.*

including particle sizes, distances, angulations, cleaning methods after abrasion, and air pressures. Analyses according to the parameters employed were used to aid in minimizing those heterogeneities. The surface treatments applied to the dentin specimens before the bond strength tests were not homogeneous either. Therefore, to minimize the clinical heterogeneity regarding surface conditions, the extracted data were separated according to same intervention-control subgroups, that is, the dentin surface treatments: no treatment, bur, SiC abrasive paper, hand excavator, or acid etching. Comparisons were restricted to same intervention-control conditions. The *in vitro* literature is known for having problems regarding good reporting practices, especially because no guidelines are available for reporting the results of the numerous types of *in vitro* tests used in dentistry. In addition, the extracted data were limited to sound dentin to reduce structural and morphologic variability regarding the dentin substrate; thus, the conclusions should not be extrapolated to caries-affected or sclerotic dentin.

Most studies included in this review tested only immediate bond strengths to dentin; that is, there was no evaluation of the effects of water degradation or other aging method on the dentin bonds. *In vitro* studies are urged to always include a storage group when testing adhesive bond strengths. Previous studies showed that differences reported between treatments in the short term were not observed when the bonded specimens were stored in water for some time before testing.[45,49] This finding is of particular importance for APA enthusiasts: the positive effects of the treatment may not persist in the long term. Therefore, it seems that the decision to apply APA to dentin should be made by the dentists, taking into account their own clinical experience; the literature cannot give a definitive answer on whether APA may effectively generate dentin bonds that last longer than non–air-abraded dentin. However, no negative effects for APA applied to dentin were observed either; thus, the treatment seems to be safe with respect to bonding to dentin.

CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

- APA with aluminum oxide particles had no negative effects on the bond strength of resin-based materials to dentin.
- In a few subgroup analyses, air abrasion was able to improve the immediate bond strength to dentin when the particle size was >30 μm and air pressure was >5 bar.
- APA duration had no significant effect on immediate dentin bond strengths.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil (Finance Code 001). The authors also acknowledge the support from CAPES/PROCAD, Brazil (grant No. 3001/2014). Authors V.P.L. and K.D.S. are grateful to CAPES for a scholarship.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 19 December 2019)

REFERENCES

1. Black RB (1945) Technic for nonmechanical preparation of cavities and prophylaxis *Journal of the American Dental Association* **32(15)** 955-965, https://doi.org/10.14219/jada.archive.1945.0129
2. Bester SP, de Wet FA, Nel JC, & Driessen CH (1995) The effect of airborne particle abrasion on the dentin smear layer and dentin: An in vitro investigation *International Journal of Prosthodontics* **8(1)** 46-50.
3. Laurell K & Hess J (1995) Scanning electron micrographic effects of air-abrasion cavity preparation on human enamel and dentin *Quintessence International* **26(2)** 139-144.
4. Horiguchi S, Yamada T, Inokoshi S, & Tagami J (1998) Selective caries removal with air abrasion *Operative Dentistry* **23(5)** 236-243.
5. Heikkinen TT, Lassila LVJ, Matinlinna JP, & Vallittu PK (2007) Effect of operating air pressure on tribochemical silica-coating *Acta Odontologica Scandinavica* **65(4)** 241-248, https://doi.org/10.1080/00016350701459753
6. Mobarak EH (2012) Effect of surface roughness and adhesive system on repair potential of silorane-based resin composite *Journal of Advanced Research* **3(3)** 279-286, https://doi.org/https://doi.org/10.1016/j.jare.2011.09.003
7. Ceci M, Pigozzo M, Scribante A, Beltrami R, Colombo M, Chiesa M, & Poggio C (2016) Effect of glycine pretreatment on the shear bond strength of a CAD/CAM resin nano ceramic material to dentin *Journal of Clinical and Experimental Dentistry* **8(2)** e146-e152, https://doi.org/10.4317/jced.52630
8. Sutil BG da S & Susin AH (2017) Dentin pretreatment and adhesive temperature as affecting factors on bond strength of a universal adhesive system *Journal of Applied Oral Science:Revista FOB* **25(5)** 533-540, https://doi.org/10.1590/1678-7757-2016-0500
9. Chimello DT, Ramos RP, Chinelatti MA, Dibb RGP, Pecora JD, & Corona SAM (2002) Effect of Er:YAG laser

and air abrasion on the tensile bond strength of two adhesive restorative systems to dentin *Journal of Oral Laser Applications* **2** 22322-9.

10. Coli P, Alaeddin S, Wennerberg A, & Karlsson S (1999) In vitro dentin pretreatment: surface roughness and adhesive shear bond strength *European Journal of Oral Sciences* **107(5)** 400-413, https://doi.org/10.1046/j.0909-8836.1999.eos107512.x

11. Dilber E & Ozturk AN (2015) Bond strength of porcelain bonded to enamel and dentin surfaces prepared with different surface treatments *Journal of Adhesion* **91(8)** 651-662, https://doi.org/10.1080/00218464.2014.959937

12. Motisuki C, Monti Lima L, Emi Sanabe M, Jacques P, & Santos-Pinto L (2006) 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*ogica **55(11-12)** 611-618.

13. Manhart J, Mehl A, Schroeter R, Obster B, & Hickel R (1999) Bond strength of composite to dentin treated by air abrasion *Operative Dentistry* **24(4)** 223-232.

14. Panah FG, Rezai SMM, & Ahmadian L (2008) The influence of ceramic surface treatments on the micro-shear bond strength of composite resin to IPS Empress 2 *Journal of Prosthodontics* **17(5)** 409-414, https://doi.org/10.1111/j.1532-849X.2007.00296.x

15. Yavuz T, Dilber E, Kara HB, Tuncdemir AR, & Ozturk AN (2013) Effects of different surface treatments on shear bond strength in two different ceramic systems *Lasers in Medical Science* **28(5)** 1233-1239, https://doi.org/10.1007/s10103-012-1201-5

16. Bottino MC, Ozcan M, Coelho PG, Valandro LF, Bressiani JC, & Bressiani AHA (2008) Micro-morphological changes prior to adhesive bonding: High-alumina and glassy-matrix ceramics *Brazilian Oral Research* **22(2)** 158-163.

17. Foxton RM, Cavalcanti AN, Nakajima M, Pilecki P, Sherriff M, Melo L, & Watson TF (2011) Durability of resin cement bond to aluminium oxide and zirconia ceramics after air abrasion and laser treatment *Journal of Prosthodontics* **20(2)** 84-92, https://doi.org/10.1111/j.1532-849X.2010.00678.x

18. Cura M, Gonzalez-Gonzalez I, Fuentes V, & Ceballos L (2016) Effect of surface treatment and aging on bond strength of composite resin onlays *Journal of Prosthetic Dentistry* **116(3)** 389-396, https://doi.org/10.1016/j.prosdent.2016.02.016

19. Wendler M, Belli R, Panzer R, Skibbe D, Petschelt A, & Lohbauer U (2016) Repair bond strength of aged resin composite after different surface and bonding treatments *Materials (Basel, Switzerland)* **9(7)** E547 https://doi.org/10.3390/ma9070547

20. Chaiyabutr Y & Kois JC (2008) The effects of tooth preparation cleansing protocols on the bond strength of self-adhesive resin luting cement to contaminated dentin *Operative Dentistry* **33(5)** 556-563, https://doi.org/10.2341/07-141

21. D'Amario M, Piccioni C, Di Carlo S, De Angelis F, Caruso S, & Capogreco M (2017) Effect of airborne particle abrasion on microtensile bond strength of total-etch adhesives to human dentin *BioMed Research International* **2017** 2432536, https://doi.org/10.1155/2017/2432536

22. Mujdeci A & Gokay O (2004) The effect of airborne-particle abrasion on the shear bond strength of four restorative materials to enamel and dentin *Journal of Prosthetic Dentistry* **92(3)** 245-249, https://doi.org/10.1016/j.prosdent.2004.05.007

23. Dietschi D & Argente A (2011) A comprehensive and conservative approach for the restoration of abrasion and erosion. Part II: Clinical Procedures and Case Report *European Journal of Esthetic Dentistry* **6(2)** 142-159.

24. Fahl Junior N (1996) The direct/indirect composite resin veneers: A case report *Practical Periodontics and Aesthetic Dentistry* **8(7)** 627-638.

25. Schlichting LH, Resende TH, Reis KR, & Magne P (2016) Simplified treatment of severe dental erosion with ultrathin CAD-CAM composite occlusal veneers and anterior bilaminar veneers. *Journal of Prosthetic Dentistry* **116(4)** 474-482, https://doi.org/10.1016/j.prosdent.2016.02.013

26. Guazzato M, Quach L, Albakry M, & Swain M V (2005) Influence of surface and heat treatments on the flexural strength of Y-TZP dental ceramic *Journal of Dentistry* **33(1)** 9-18, https://doi.org/10.1016/j.jdent.2004.07.001

27. Zhang Y, Lawn BR, Rekow ED, & Thompson VP (2004) Effect of sandblasting on the long-term performance of dental ceramics *Journal of Biomedical Materials Research. Part B, Applied Biomaterials* **71(2)** 381-386, https://doi.org/10.1002/jbm.b.30097

28. Agger MS, Horsted-Bindslev P, & Hovgaard O (2001) Abrasiveness of an air-powder polishing system on root surfaces in vitro *Quintessence International* **32(5)** 407-411.

29. Burnett LHJ, Conceicao EN, Pelinos JE, & Eduardo CD (2001) 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 *Journal of Clinical Laser Medicine & Surgery* **19(4)** 199-202, https://doi.org/10.1089/104454701316918970

30. Chaves P, Giannini M, & Ambrosano GMB (2002) Influence of smear layer Pretreatment on bond strength to dentin *Journal of Adhesive Dentistry* **4(3)** 191-196.

31. Pilo R, Cardash HS, Oz-Ari B, & Ben-Amar A (2001) Effect of preliminary treatment of the dentin surface on the shear bond strength of resin composite to dentin *Operative Dentistry* **26(6)** 569-575.

32. Rafael CF, Quinelato V, Morsch CS, DeDeus G, & Reis CM (2016) Morphological analysis of dentin surface after conditioning with two different methods: Chemical and mechanical *Journal of Contemporary Dental Practice* **17(1)** 58-62.

33. Anja B, Walter D, Nicoletta C, Marco F, Pezelj Ribaric S, & Ivana M (2015) Influence of air abrasion and sonic technique on microtensile bond strength of one-step self-etch adhesive on human dentin *Scientific World Journal* **2015** 368745, https://doi.org/10.1155/2015/368745

34. Carvalho EM, Lima DM, Carvalho CN, Loguercio AD, Martinelli JR, & Bauer J (2015) Effect of airborne-particle abrasion on dentin with experimental niobophosphate bioactive glass on the microtensile bond strength of resin cements *Journal of Prosthodontic Research* **59(2)** 129-135, https://doi.org/10.1016/j.jpor.2015.01.001

35. Cebe MA, Ozturk B, & Karaarslan ES (2016) Effect of caries removal techniques on bond strength to caries affected dentin on gingival wall: AFM observation of dentinal surface *Practical Procedures & Aesthetic Dentistry* **30** 157-170, https://doi.org/10.1080/01694243.2015.1093339

36. Flury S, Peutzfeldt A, & Lussi A (2015) Two pretreatments for bonding to non-carious cervical root dentin *American Journal of Dentistry* **28(6)** 362-366.

37. Geitel B, Wischnewski R, Jahn K-R, Barthel RC, Zimmer S, & Roulet J-F (2004) Tensile bond strength of composite to air-abraded dentin. *Operative Dentistry* **29(1)** 69-74.

38. Ilday N, Güngör H, & Duymuş ZY (2011) Dentine treatment effects on bonding strength of adhesive resin cements *Materials Research Innovations* **15(3)** 202-207, https://doi.org/10.1179/143307511X13018917925784

39. Moher D, Liberati A, Tetzlaff J, & Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement *Journal of Clinical Epidemiology* **62(10)** 1006-1012, https://doi.org/10.1016/j.jclinepi.2009.06.005

40. Higgins J & Green S (2011) *Cochrane Handbook for Systematic Reviews of Interventions* The Cochrane Collaboration, London, UK.

41. Rosa WL, Piva E, & Silva AF (2015) Bond strength of universal adhesives: A systematic review and meta-analysis *Journal of Dentistry* **43(7)** 765-776, https://doi.org/10.1016/j.jdent.2015.04.003

42. Sedrez-Porto JA, Rosa WL, da Silva AF, Munchow EA, & Pereira-Cenci T (2016) Endocrown restorations: A systematic review and meta-analysis *Journal of Dentistry* **52** 8-14, https://doi.org/10.1016/j.jdent.2016.07.005

43. Leite FR, Capote TS, & Zuanon AC (2005) Application of the total etching technique or self-etching primers on primary teeth after air abrasion *Brazilian Oral Research* **19(3)** 198-202, https://doi.org/10.1590/S1806-83242005000300008

44. Ahid F, Andrade MF, Campos EA, Luscino F, & Vaz LG (2004) Influence of different dentin etching times and concentrations and air-abrasion technique on dentin microtensile bond strength *American Journal of Dentistry* **17(6)** 447-450.

45. Zimmerli B, De Munck J, Lussi A, Lambrechts P, & Van Meerbeek B (2012) Long-term bonding to eroded dentin requires superficial bur preparation *Clinical Oral Investigations* **16(5)** 1451-1461, https://doi.org/10.1007/s00784-011-0650-8

46. Los SA & Barkmeier WW (1994) Effects of dentin air abrasion with aluminum oxide and hydroxyapatite on adhesive bond strength *Operative Dentistry* **19(5)** 169-175.

47. Moritz A, Schoop U, Goharkhay K, Szakacs S, Sperr W, Schweidler E, Wernisch J, & Gutknecht N (1998) Procedures for enamel and dentin conditioning: A comparison of conventional and innovative methods *Journal of Esthetic Dentistry* **10(2)** 84-93.

48. Roeder LB, Berry EA III, You C, & Powers JM (1995) Bond strength of composite to air-abraded enamel and dentin. *Operative Dentistry* **20(5)** 186-190.

49. Abo-hamar SE, Federlin M, Hiller K, Friedl K, & Schmalz G (2005) Effect of temporary cements on the bond strength of ceramic luted to dentin *Dental Materials* 794-803, https://doi.org/10.1016/j.dental.2005.01.015.

50. Souza-Zaroni WC, Chinelatti MA, Delfino CS, Pécora JD, Palma-Dibb RG, & Corona SAM (2008) Adhesion of a self-etching system to dental substrate prepared by Er:YAG laser or air abrasion *Journal of Biomedical Materials Research. Part B, Applied Biomaterials* **86(2)** 321-329, https://doi.org/10.1002/jbm.b.31020

51. França FMG, Santos AJS, & Lovadino JR (2007) Influence of air abrasion and long-term storage on the bond strength of self-etching adhesives to dentin *Operative Dentistry* **32(3)** 217-224, https://doi.org/10.2341/06-61

52. Freeman R, Varanasi S, Meyers IA, & Symons AL (2012) 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 *Dental Materials Journal* **31(2)** 180-188, https://doi.org/10.4012/dmj.2011-146

53. Malkoc MA, Taşdemir ST, Ozturk AN, Ozturk B, & Berk G (2011) Effects of laser and acid etching and air abrasion on mineral content of dentin *Lasers in Medical Science* **26(1)** 21-27, https://doi.org/10.1007/s10103-009-0751-7

54. Sazak H, Turkmen C, & Gunday M (2001) Effects of Nd: YAG laser, air-abrasion and acid-etching on human enamel and dentin *Operative Dentistry* **26(5)** 476-481.

55. Tada K, Wiroj S, Inatomi M, & Sato S (2012) The characterization of dentin defects produced by air polishing *Odontology* **100(1)** 41-46, https://doi.org/10.1007/s10266-011-0019-0

56. Majd H, Viray J, Porter JA, Romberg E, & Arola D (2012) Degradation in the fatigue resistance of dentin by bur and abrasive air-jet preparations *Journal of Dental Research* **91(9)** 894-899, https://doi.org/10.1177/0022034512455800

57. Tada K, Oda H, Inatomi M, & Sato S (2014) Characterization and *Streptococcus mutans* adhesion on air polishing dentin *Odontology* **102(2)** 284-289, https://doi.org/10.1007/s10266-013-0109-2

58. Bühler J, Schmidli F, Weiger R, & Walter C (2015) Analysis of the effects of air polishing powders containing sodium bicarbonate and glycine on human teeth *Clinical Oral Investigations* **19(4)** 877-885, https://doi.org/10.1007/s00784-014-1317-z

59. Antunes LAAA, Salgado VE, Antunes LA, & Maia LC (2014) Air abrasion: effect on cavity preparation and on microleakage in primary teeth *Revista Odonto Ciência* **29(4)** 119-124, https://doi.org/10.15448/1980-6523.2014.4.17335

60. Anusavice KJ, Phillips RW, Shen C, & Rawls HR (2013) *Phillips' Science of Dental Materials* **12th edition** Elsevier/Saunders, St. Louis, Missouri.

61. Manhart J, Chen HY, Kunzelmann KH, & Hickel R (1999) Bond strength of a compomer to dentin under various surface conditions *Clinical Oral Investigations* **3(4)** 175-180, https://doi.org/10.1007/s007840050098

62. de Oliveira MT, de Freitas PM, de Paula Eduardo C, Ambrosano GMB, & Giannini M (2007) Influence of diamond sono-abrasion, air-abrasion and Er:YAG laser irradiation on bonding of different adhesive systems to dentin *European Journal of Dentistry* **1(3)** 158–166, https://doi.org/10.3290/j.jad.a29554

63. Pahlavan A, Mehmanchi M, Omrani LR, & Chiniforush N (2013) Effect of air abrasion and erbium-doped yttrium aluminum garnet (er: Yag) laser preparation on shear bond strength of composite to dentin *Journal of Lasers in Medical Sciences* **4(3)** 127–130.

64. Santos MJMC, Bapoo H, Rizkalla AS, & Santos GC (2011) Effect of dentin-cleaning techniques on the shear bond strength of self-adhesive resin luting cement to dentin *Operative Dentistry* **36(5)** 512–520, https://doi.org/10.2341/10-392-L

65. Santos MJMC, Costa MD, Maria H, Rêgo C, Rubo JH, & Santos GC (2017) Effect of surface treatments on the bond strength of self-etching adhesive agents to dentin *General Dentistry* **65(4)** e1–e6.

66. Soares CJ, Castro CG, Santos Filho PCF, & da Mota AS (2007) Effect of previous treatments on bond strength of two self-etching adhesive systems to dental substrate *Journal of Adhesive Dentistry* **9(3)** 291–296.

67. Van Meerbeek B, De Munck J, Mattar D, Van Landuyt K, & Lambrechts P (2003) Microtensile bond strengths of an etch&rinse and self-etch adhesive to enamel and dentin as a function of surface treatment *Operative Dentistry* **28(5)** 647–660.

68. Yazici AR, Karaman E, Ertan A, Özgünaltay G, & Dayangaç B (2009) Effect of different pretreatment methods on dentin bond strength of a one-step self-etch adhesive *Journal of Contemporary Dental Practice* **10(1)** 41–48, https://doi.org/10.5005/jcdp-10-1-41