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ORIGINAL ARTICLE

Dentistry

Shear Bond Strength of Two Self-Etching Adhesives to Air-Abraded Dentin: An in Vitro Study

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Abstract

Background: The aim of this research was to study the effect of air-abrasive treatment of dentin on the chemical composition of its surface and the adhesion strength of 2 self-etching adhesive systems (AS).

Methods and Results: Powders based on aluminum oxide (Al_2O_3) (27µm) (KaVo, Biberach, Germany), sodium bicarbonate (NaHCO3) (40µm) (AIR-FlOW Classic Comfort, EMS, Nyon, Switzerland), and erythritol (14µm) (AIR-FLOW Plus, EMS, Nyon, Switzerland) were used for the air-abrasive treatment of adhesive surfaces. Bonding steps were carried out with Single Bond Universal (SBU) (3M ESPE, USA) and Bond Force 2 (BF2) (Toquyama, Japan). The adhesion strength of composite to dentin was evaluated on 80 samples prepared in accordance with the Ultradent Shear Bond Strength test. All samples were divided into 4 groups depending on the method of dentin surface processing. In the samples of Group 1 (n=20), aluminum oxide was used for the air-abrasive treatment of dentin. In Group 2 (n=20) and Group 3 (n=20), samples were treated using powders based on sodium bicarbonate and erythritol, respectively. Group 4 (control, n=20) included tooth samples in which the dentin surface was not air-abraded after preparation with carbide burs. Then, each group was divided into 2 subgroups (Sub-A and Sub-B) depending on the type of adhesive system used. Adhesive resin was applied and polymerized in accordance with the manufacturer's instructions. Single Bond Universal (SBU) was used for the samples of Sub-A, and Bond Force 2 (BF2) (Toquyama, Japan) was used for the samples of Sub-B. Scanning electron microscopy and determining the surface elemental composition of samples were carried out on an SEM-EVO MA 10 (Carl Zeiss) and energy dispersive X-ray spectrometer with EDS Aztec Energy Advanced X-Act (Oxford Instruments). It was concluded that air-abrasive treatment of the dentin surface does not enhance the adhesion strength of composite material when using self-etch AS. Also, it was noted that the pH level of self-etch AS is not a crucial feature in determining the strength of the filling-tooth interface. The resulting variations in the elemental composition of dentin surface after air-abrasion with various mixtures and their effect on the efficacy of the different AS require further in vitro studies.(**International Journal of Biomedicine. 2022;12(4):591-595.**).

Keywords: air-abrasion • adhesive systems • dentin surface

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Abbreviations

AA, air-abrasion; **AS,** adhesive systems; **SBU**, Single Bond Universal; **BF2**, Bond Force 2.

Introduction

Modern trends in minimally invasive cavity preparation, combined with the advent of self-etching adhesive systems (AS), have conceptually changed the philosophy of dental caries operative treatment.(1-5) Alternative methods of tooth preparation allow performing dental care, considering the microscopic surface features of enamel and dentin.(6-11)

Removing biofilm and the smear layer without a clinically significant impact on hard tooth tissues became possible due to the introduction into the practice of low abrasive powders based on glycine, erythritol, trehalose, etc.(12-14) At the same time, the variety of clinical situations and increasing complexity of comprehensive tooth care unfortunately do not allow the complete abandonment of coarse-grained air-abrasive mixtures based on aluminum oxide, sodium bicarbonate, calcium carbonate, and many other substances.[15-17] Recent attempts have also been made to combine the removal of stains and tissue debris of the smear layer with a guided biofilm therapy and the formation of a bioactive layer on the surface of the tooth to promote accelerated remineralization of dentin and enamel weakened by the carious pathology.[18,19]

Therefore, the current techniques of tooth surface preparation with consideration of the features of adhesive and restorative materials can contribute to reliable and long-term restorations.

The modern concept of simultaneous etching and hybridization of hard tooth tissues is another step toward minimally invasive dentistry, and it was embodied in AS of the sixth and seventh generations.[20,21] It is important to emphasize that one of the bad features of total-etch AS is considered to be incomplete infiltration by monomers of microgaps created after etching with phosphoric acid in the surface layers of enamel and dentin.[22,23] Moreover, moisture in the demineralized extracellular matrix of dentin causes gel polymerization of Etch&Rinse adhesive monomers resulting in the formation of hydrolytically unstable polymers in a hybrid layer.[24,25

The above and many other shortcomings related to total-etch AS were considered when a new group of self-etching adhesives based on acidic monomers was introduced. The positive aspects of these adhesives are the absence of mandatory acid etching of dentin and the formation of a chemical bond between the hydroxyapatite of hard tooth tissues and adhesive resin monomers.[26,27] Also, the chemistry and mode of application of one-step bonding materials imply the incorporation of a smear layer into the structure of the adhesive layer.[28]

In this regard, it can be assumed that the composition and amount of the smear layer may affect the bond strength of the composite to tooth dentin when using self-etching adhesives.[29]

It is known that air-abrasion of prepared dentin can open a significant number of orifices of dentinal tubules and facilitate the formation of a thinner smear layer.[30] However, considering the experience of previous studies, this method may cause changes in the chemical composition of dentin surfaces and affect the strength of composite adhesion.[31,32

The aim of this research was to study the effect of air-abrasive treatment of dentin on the chemical composition of its surface and the adhesion strength of 2 self-etching adhesive systems (AS).

Materials and Methods

Powders based on aluminum oxide (Al_2O_3) (27μm) (KaVo, Biberach, Germany), sodium bicarbonate (NaHCO3) (40μm) (AIR-FlOW Classic Comfort, EMS, Nyon, Switzerland), and erythritol (14μm) (AIR-FLOW Plus, EMS, Nyon, Switzerland) were used for the air-abrasive treatment of adhesive surfaces. Bonding steps were carried out with Single Bond Universal (SBU) (3M ESPE, USA) and Bond Force 2 (BF2) (Toquyama, Japan). The adhesion strength of composite to dentin was evaluated on 80 samples prepared in accordance with the Ultradent Shear Bond Strength test.

To obtain a uniform smear layer, the exposed tooth surfaces on all samples were processed with carbide burs under constant water cooling and then washed with water spray for 30 seconds using an air-water syringe of a dental unit.

All samples were divided into 4 groups depending on the method of dentin surface processing. In the samples of Group 1 (n=20), aluminum oxide was used for the air-abrasive treatment of dentin. In Group 2 (n=20) and Group 3 (n=20), samples were treated using powders based on sodium bicarbonate and erythritol, respectively. Group 4 (control, n=20) included tooth samples in which the dentin surface was not air-abraded after preparation with carbide burs. In each case of air-abrasion, the nozzle of the handpiece was angulated at 45° to the dentin surface. The treatment was carried out with a constant flow of particles under 0.25MPa pressure for 30 seconds, slowly moving a nozzle with sweeping motions above the surface of tooth samples at a distance of 5mm, after which they were thoroughly washed with an air-water spray for 30 seconds.

Then, each group was divided into 2 subgroups (Sub-A and Sub-B) depending on the type of adhesive system used. Adhesive resin was applied and polymerized in accordance with the manufacturer's instructions. SBU was used for the samples of Sub-A, and BF2 (Toquyama, Japan) was used for the samples of Sub-B. The light-curing composite Herculite XRV (Kerr, Italy) served as a material of choice. The polymerization was carried out using a VALO lamp (Ultradent Products Inc., USA) in a standard mode. The one-day adhesive strength of bonded interfaces without aging simulation was evaluated on an UltraTester device (Ultradent Products Inc., USA). The speed of movement of the test clamp was set to 1mm/min. The top value of bonding failure was fixed in pounds.

Scanning electron microscopy and determining the surface elemental composition of samples were carried out on an SEM-EVO MA 10 (Carl Zeiss) and energy dispersive X-ray spectrometer with EDS Aztec Energy Advanced X-Act (Oxford Instruments). There were 12 additional tooth samples, which were divided into 3 groups. Each sample had 2 different areas on the dentin surface, which were subjected to air-abrasion and carbide bur (machined) processing. For air-abrasion, in the A/M group (n=4), B/M group (n=4), and E/M group (n=4), alumina particles, bicarbonate, and erythritol mixtures, respectively, were applied.

Statistical analysis was performed using StatSoft Statistica v6.0. For descriptive analysis, results are presented as mean±standard deviation (SD). Multiple comparisons were made with one-way ANOVA and post-hoc Tukey HSD test. The Mann-Whitney U Test was used to compare the differences between the two independent groups. A probability value of $P<0.05$ was considered statistically significant.

Results

It was revealed that the adhesive strength of composite material to tooth dentin depends on the type of powder used for air-abrasion and the kind of adhesive system applied (Table 1). When compared with the control (Sub-4A), air-abrasion of the dentin surface with powders based on alumina (Sub-1A), sodium bicarbonate (Sub-2A), and erythritol (Sub-3A) did not adversely affect the strength of adhesion when SBU was used.

In the case of BF2, there was no statistical difference between the control (Sub-4B) and Sub-1B. However, we found a statistically significant decrease in the strength of adhesion in samples of Sub-2B by 1.2 times (*P*=0.012) and Sub-B3 by 1.7 times (*P*=0.000), compared to Sub-4B.

Changes in the elemental composition of dentin surfaces after air-abrasion with different mixtures were predictable to a certain extent (Table 2). Along with the minor variations in the level of basic elements of dentin, the appearance of aluminum and silicon ions was noted after exposure to powders based on aluminum oxide, sodium bicarbonate, and erythritol.

An increase in Al+ content by 8.3 times was found after air-abrasion of dentin surfaces in samples of the A/M group (*P*=0.000). Also, Na+ content grew by 1.28 times in the B/M group (*P*<0.05). The same tendency in Si+ content by 1.5 times was noted in the B/M and E/M samples; however, these changes were not statistically significant (*P*>0.05).

An unexpected 1.5-times elevation of Mg+ (*P*<0.05) was registered on dentin surfaces after air-abrasion with erythritol-based powder. However, the level of the element in the E/M group did not significantly differ from the value obtained after dentin treatment with Al_2O_3 powder in A/M samples. The high content of C+ after dentin surface processing with a carbide bur in samples of the E/M group was assumed for the contamination of scanning areas.

Discussion

A huge amount of research has been devoted to the problem of integrating dental composite with dentin, which is directly related to a large number of factors that affect the quality of adhesion and hence the longevity of restorations.[33-36] Also, the complex ultrastructure of adhesive surfaces and technical problems associated with AS of fourth and fifth generations can negatively affect the quality of dental treatment when composite materials are applied.[37,38]

That is why the use of self-etching adhesive monomers on dentin appears to be the most promising.[39] However, considering the mode of interaction of these materials with hard tooth tissues, the method of its application, and the presence

Table 1.

Adhesion strength of composite to tooth dentin in groups (lb).

Group/ Subgroup	Group 1	Group 2	Group 3	Group 4	Statistics
Subgroup A	24.57±4.72	21.42±2.03	21.82±4.7	23.53±2.27	F=1.6220 P=0.2013
Subgroup B	15.56±1.72	13.57±2.3	9.9±2.96	16.47±2.35	F=15.0697 P=0.000 P_{1B-2B}=0.2567 P_{1B-3B}=0.0000 P_{1B-4B}=0.8265 P_{2B-3B}=0.0074 P_{2B-4B}=0.0457 P_{3B-4B}=0.0000
P-value	<0.0001	<0.0001	<0.0001	<0.0001	

Table 2.

Elemental composition of dentin surfaces after processing with different methods.

Groups		C^+	O^-	Na^+	Mg^+	Ca^+	P^+	Al^+	Si^+
A/M	Al_2O_3 abraded	16.02±0.56	41.23±1.45	0.55±0.1	0.75±0.05	28.1±0.67	13.62±0.3	0.25±0.05	0.07±0.05
	P-value	>0.05	>0.05	>0.05	>0.05	<0.05	<0.05	0.000	>0.05
	Machined	15.53±0.8	39.45±0.39	0.57±0.052	0.67±0.05	29.4±0.47	14.23±0.21	0.03±0.05	0.05±0.05
B/M	Bicarbonate abraded	15.26±1.04	39.03±0.9	0.87±0.11	0.63±0.05	29.7±0.87	14.16±0.33	0.03±0.05	0.27±0.11
	P-value	>0.05	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05	>0.05
	Machined	16.25±1.15	38.3±0.66	0.68±0.1	0.57±0.12	29.87±1.22	14.12±0.57	0.02±0.04	0.18±0.1
Э/M	Erythritol abraded	16.82±0.65	40±0.49	0.62±0.07	0.82±0.04	27.78±0.31	14.08±0.71	0.02±0.04	0.18±0.07
	P-value	<0.05	<0.05	>0.05	<0.05	<0.05	<0.05	>0.05	>0.05
	Machined	20.63±0.61	38.27±0.29	0.55±0.05	0.55±0.05	26.75±0.33	13.07±0.16	0.07±0.05	0.12±0.04

of a smear layer that is amorphous and weakly adhered to the underlying dentin may cause particular concern.[40]

In the available literature, there is a sufficient amount of data indicating the effective use of air-abrasive methods concerning cleaning the tooth surface from dentin debris and enamel fragments that appear after traditional preparation with diamond and carbide burs. However, the results of studies that assume to improve the adhesion strength of a composite to abraded dentin may go either way.[18,41-43] In this regard, the main purpose of this study was to evaluate the effect of various air-abrasive mixtures on the adhesion strength of composite to dentin when self-etching AS are used. It is well known that adhesive materials of the sixth and seventh generations create mechanical and chemical bonds with dentin and enamel hydroxyapatite due to the unique properties of acidic monomers.[26,27] That is why, considering the appearance of possible changes on the surface of abraded dentin, a comparative analysis of its elemental composition was also carried out. It was previously noted that self-etching AS might have a different pH, and based on the pH, they are divided into very weak (ultra-mild, pH≥2.5), weak (mild, pH≈2), medium (intermediate, pH≈1.5), and strong (strong, pH≤1). It has also been found that the depth of demineralization of hard tooth tissues directly relates to the pH level of self-etch AS.[44] Hence to reduce the level of subjectivity, we used SBU and BF2 adhesives in the study, which are slightly different from each other in terms of acidity and have pH of 2.7 and 2.8, respectively.

Results of the study demonstrated that in the case of SBU, an air-abrasion of the dentin surface with Al_2O_3 (27μm), AIR-FLOW Classic, and AIR-FLOW Plus did not cause a clinically significant variation in values of adhesion strength of composite to dentin.

However, the same processing of the dentin surface led to a significant decrease in bond strength between resin and tooth when BF2 was applied, whereas the differences were significant after abrasion with sodium bicarbonate and erythritol-based powders.

Concerning changes in the elemental composition of the dentin surface after treatment with Al_2O_3 powder (27μm), a significant increase in Al+ and a decrease in Ca+ and P+ were noted, presumably indicating the decrease in the number of hydroxyapatite crystals in the scanning sectors. However, the revealed changes were not a reason for significant variations in the bond strength values for the SBU and BF2. The accumulation of Na+ on the dentin surface after treatment with AIR-FLOW Classic powder could be one of the possible reasons for the deterioration of composite adhesion when BF2 was used. Also, the most dramatic reduction in composite bond strength with BF2 was observed after dentine treatment with AIR-FLOW Plus despite a relative increase in the surface level of Ca+ and P+. Therefore, it was concluded that air-abrasive treatment of the dentin surface does not enhance the adhesion strength of composite material when using self-etch AS. Also, it was noted that the pH level of self-etch AS is not a crucial feature in determining the strength of the filling-tooth interface. The resulting variations in the elemental composition of dentin surface after air-abrasion with various mixtures and their effect on the efficacy of the different AS require further in vitro studies.

Competing Interests

The authors declare that they have no competing interests.

References

1. Banerjee A, Watson TF. Pickard's Manual of Operative Dentistry, 9th edition. Oxford, UK: OUP Oxford; 2011
2. Hegde VS, Khatavkar RA. A new dimension to conservative dentistry: Air abrasion. J Conserv Dent. 2010 Jan;13(1):4-8. doi: 10.4103/0972-0707.62632.
3. 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. doi: 10.1016/j.dental.2010.10.023.
4. Foxton RM. Current perspectives on dental adhesion: (2) Concepts for operatively managing carious lesions extending into dentine using bioactive and adhesive direct restorative materials. Jpn Dent Sci Rev. 2020 Nov;56(1):208-215. doi: 10.1016/j.jdsr.2020.08.003.
5. Melkumyan TV, Kakhkharova DJ, Dadamova AD; Kamilov NKh, Siddikova SSh, Rakhmatullaeva ShI, Masouleh SM. Comparative Analysis of *in vitro* Performance of Total-Etch and Self-Etch Adhesives. International Journal of Biomedicine.2016;6(4):283-286. doi: 10.21103/Article6(4)OA7.
6. Bornstein ES. Why wavelength and delivery systems are the most important factors in using a dental hard-tissue laser: a literature review. Compend Contin Educ Dent. 2003 Nov;24(11):837-8, 841, 843 passim; quiz 848.
7. Iaria G. Clinical, morphological, and ultrastructural aspects with the use of Er:YAG and Er,Cr:YSGG lasers in restorative dentistry. Gen Dent. 2008 Nov-Dec;56(7):636-9.
8. Lin T, Aoki A, Saito N, Yumoto M, Nakajima S, Nagasaka K, et al. Dental hard tissue ablation using mid-infrared tunable nanosecond pulsed Cr:CdSe laser. Lasers Surg Med. 2016 Dec;48(10):965-977. doi: 10.1002/lsm.22508.
9. de Oliveira MT, de Freitas PM, de Paula Eduardo C, Ambrosano GM, 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.
10. Anja B, Walter D, Nicoletta C, Marco F, Pezelj Ribarić 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. doi: 10.1155/2015/368745.
11. Lima VP, Soares K, Caldeira VS, Faria-E-Silva AL, Loomans B, Moraes RR. Airborne-particle Abrasion and Dentin Bonding: Systematic Review and Meta-analysis. Oper Dent. 2021 Jan 1;46(1):E21-E33. doi: 10.2341/19-216-L.
12. Moëne R, Décaillet F, Andersen E, Mombelli A. Subgingival plaque removal using a new air-polishing device. J Periodontol. 2010 Jan;81(1):79-88. doi: 10.1902/jop.2009.090394.
13. Kröger JC, Haribyan M, Nergiz I, Schmage P. Air polishing with erythritol powder - In vitro effects on dentin loss. J Indian Soc Periodontol. 2020 Sep-Oct;24(5):433-440. doi: 10.4103/jisp.jisp_414_19.
14. Kruse AB, Akakpo DL, Maamar R, Woelber JP, Al-Ahmad A, Vach K, Ratka-Krueger P. Trehalose powder for subgingival air-polishing during periodontal maintenance therapy: A randomized controlled trial. J Periodontol. 2019 Mar;90(3):263-270. doi: 10.1002/JPER.17-0403.

15. Kofford KR, Wakefield CW, Murchison DF. Aluminum oxide air abrasion particles: a bacteriologic and SEM study. Quintessence Int. 2001 Mar;32(3):243-8.
16. Johnson King O, Milly H, Boyes V, Austin R, Festy F, Banerjee A. The effect of air-abrasion on the susceptibility of sound enamel to acid challenge. J Dent. 2016 Mar;46:36-41. doi: 10.1016/j.jdent.2016.01.009.
17. Barnes CM, Covey D, Watanabe H, Simetich B, Schulte JR, Chen H. An in vitro comparison of the effects of various air polishing powders on enamel and selected esthetic restorative materials. J Clin Dent. 2014;25(4):76-87.
18. Sauro S, Watson TF, Thompson I, Banerjee A. One-bottle self-etching adhesives applied to dentine air-abraded using bioactive glasses containing polyacrylic acid: an in vitro microtensile bond strength and confocal microscopy study. J Dent. 2012 Nov;40(11):896-905. doi: 10.1016/j.jdent.2012.07.004.
19. Spagnuolo G, Pires PM, Calarco A, Peluso G, Banerjee A, Rengo S, Elias Boneta AR, Sauro S. An in-vitro study investigating the effect of air-abrasion bioactive glasses on dental adhesion, cytotoxicity and odontogenic gene expression. Dent Mater. 2021 Nov;37(11):1734-1750. doi: 10.1016/j.dental.2021.09.004.
20. 20 Giannini M, Makishi P, Ayres AP, Vermelho PM, Fronza BM, Nikaido T, Tagami J. Self-etch adhesive systems: a literature review. Braz Dent J. 2015 Jan-Feb;26(1):3-10. doi: 10.1590/0103-6440201302442.
21. Ozer F, Blatz MB. Self-etch and etch-and-rinse adhesive systems in clinical dentistry. Compend Contin Educ Dent. 2013 Jan;34(1):12-4, 16, 18; quiz 20, 30. PMID: 23550327.
22. Pashley DH, Tay FR, Breschi L, Tjäderhane L, Carvalho RM, Carrilho M, Tezvergil-Mutluay A. State of the art etch-and-rinse adhesives. Dent Mater. 2011 Jan;27(1):1-16. doi: 10.1016/j.dental.2010.10.016.
23. Hashimoto M, Ito S, Tay FR, Svizero NR, Sano H, Kaga M, Pashley DH. Fluid movement across the resin-dentin interface during and after bonding. J Dent Res. 2004 Nov;83(11):843-8. doi: 10.1177/154405910408301104.
24. Paul SJ, Leach M, Rueggeberg FA, Pashley DH. Effect of water content on the physical properties of model dentine primer and bonding resins. J Dent. 1999 Mar;27(3):209-14. doi: 10.1016/s0300-5712(98)00042-6.
25. Cadenaro M, Breschi L, Rueggeberg FA, Suchko M, Grodin E, Agee K, Di Lenarda R, Tay FR, Pashley DH. Effects of residual ethanol on the rate and degree of conversion of five experimental resins. Dent Mater. 2009 May;25(5):621-8. doi: 10.1016/j.dental.2008.11.005.
26. Perdigão J, Frankenberger R, Rosa BT, Breschi L. New trends in dentin/enamel adhesion. Am J Dent. 2000 Nov;13(Spec No):25D-30D.
27. 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. doi: 10.1016/j.dental.2010.10.023.
28. Saikaew P, Sattabanasuk V, Harnirattisai C, Chowdhury AFMA, Carvalho R, Sano H. Role of the smear layer in adhesive dentistry and the clinical applications to improve bonding performance. Jpn Dent Sci Rev. 2022 Nov;58:59-66.
29. Suyama Y, Lührs AK, De Munck J, Mine A, Poitevin A, Yamada T, Van Meerbeek B, Cardoso MV. Potential smear layer interference with bonding of self-etching adhesives to dentin. J Adhes Dent. 2013 Aug;15(4):317-24. doi: 10.3290/j.jad.a29554.
30. Melkumyan TV, Musashaykhova ShK, Daurova FYu, Kamilov NKh, Sheraliyeva SSh, Dadamova AD. Effect of Air-Abrasion on Shear Bond Strength of Resin Composite to Dentin: A Study in Vitro International Journal of Biomedicine.2021;11(4):451-455. doi:10.21103/Article11(4)_OA10.
31. Melkumyan TV, Seeberger GK, Khabadze ZS, Kamilov NKh, Makeeva MK, Dashtieva MU, et al. Air Abrasion of Titanium Dental Implants with Water-Soluble Powders: An In Vitro Study International Journal of Biomedicine. 2022;12(3):428-432. doi:10.21103/Article12(3)_OA15.
32. Bester SP, de Wet FA, Nel JC, Driessen CH. The effect of airborne particle abrasion on the dentin smear layer and dentin: an in vitro investigation. Int J Prosthodont. 1995 Jan-Feb;8(1):46-50.
33. Hellyer P. The longevity of composite restorations. Br Dent J. 2022 Apr;232(7):459. doi: 10.1038/s41415-022-4163-4.
34. Opdam NJ, van de Sande FH, Bronkhorst E, Cenci MS, Bottenberg P, Pallesen U, Gaengler P, Lindberg A, Huysmans MC, van Dijken JW. Longevity of posterior composite restorations: a systematic review and meta-analysis. J Dent Res. 2014 Oct;93(10):943-9. doi: 10.1177/0022034514544217.
35. Kubo S. Longevity of resin composite restorations. Japanese Dental Science Review. 2011;47(1):43-55. doi:10.1016/j.jdsr.2010.05.002.
36. Melkumyan TV, Makhamadaminova KD, Kamilov EKh. Clinical and Experimental Evaluation of the Effectiveness of «Soft-Start» Polymerization in Dental Composite Restoration. International Journal of Biomedicine. 2012;2(3):242-245
37. Goldberg M, Kulkarni AB, Young M, Boskey A. Dentin: structure, composition and mineralization. Front Biosci (Elite Ed). 2011 Jan 1;3(2):711-35. doi: 10.2741/e281.
38. Scotti N, Bergantin E, Giovannini R, Delbosco L, Breschi L, Migliaretti G, Pasqualini D, Berutti E. Influence of multi-step etch-and-rinse versus self-etch adhesive systems on the post-operative sensitivity in medium-depth carious lesions: An in vivo study. Am J Dent. 2015 Aug;28(4):214-8.
39. Gupta A, Tavane P, Gupta PK, Tejolatha B, Lakhani AA, Tiwari R, Kashyap S, Garg G. Evaluation of Microleakage with Total Etch, Self-Etch and Universal Adhesive Systems in Class V Restorations: An In vitro Study. J Clin Diagn Res. 2017 Apr;11(4):ZC53-ZC56.
40. Pashley DH. Smear layer: overview of structure and function. Proc Finn Dent Soc. 1992;88 Suppl 1:215-24.
41. Banerjee A, Watson TF. Air abrasion: its uses and abuses. Dent Update. 2002 Sep;29(7):340-6. doi: 10.12968/denu.2002.29.7.340.
42. 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. doi: 10.1016/j.prosdent.2004.05.007.
43. 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.
44. Poggio C, Beltrami R, Scribante A, Colombo M, Chiesa M. Shear bond strength of one-step self-etch adhesives: pH influence. Dent Res J (Isfahan). 2015 May-Jun;12(3):209-14.

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