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THE IMPACT OF APPLICATION MODE OF THREE UNIVERSAL ADHESIVES WITH DIFFERENT CHEMICAL COMPOSITIONS AND CURING TECHNIQUES ON THEIR MICRO SHEAR BOND STRENGTH TO DENTIN

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ABSTRACT

Statement of problem: Different types of universal adhesives with different curing techniques are present in the market. The effect of their application modes on their performance is still unknown. Objectives: To test three universal adhesives with different curing techniques and their bonding ability to dentin when applied in different application modes.

Methods: Self cure Palfique Universal Bond (PUB), light cure One Coat 7 Universal Bond (1C) with and without One Coat 7.0 Activator (+/- SCA) and light cure All-bond universal (ABU) and Filtek supreme flowable composite were used. The three adhesives were used in etch-and-rinse (ER) and self-etch (SE) mode to bovine dentin. Microshear bond strength (SBS) was tested. For each group 3 teeth were prepared with 15 Microshear bond specimens. Data was collected and analyzed using R statistical analysis software version 4.1.3 for Windows.

Results: Among groups, 1C showed the highest SBS values irrespective to application mode while PUB showed lower SBS in both modes compared to other used adhesives. In the ER mode only, PUB showed significantly lower SBS values compared to other tested adhesives, no significant differences were present between the 1C +/- SCA and ABU. In SE, both 1C + SCA and PBU presented significantly lower SBS compared with other groups, while 1C showed significant higher SBS.

Conclusions: All adhesives performed better in ER mode compared to SE mode except for PUB. Significance: ER mode did not negatively affect the bonding performance to dentin and the variation of results in both application modes was adhesive dependent.

KEYWORDS: Universal adhesives, curing techniques, application modes

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INTRODUCTION

Since the introduction of resin-based restorations, their longevity was based on the bond strength and durability of the adhesive joint. Hence, manufacturers kept on developing different adhesive systems that aimed to increase bond strength with enamel and dentin as well as decrease technique sensitivity and clinical steps. In the effort to do so, universal adhesives also known as multimode adhesives were introduced in the field of dentistry. Since then, this category of adhesives has become increasingly trendy due to the ability to be applied in self-etch (SE) as well as etch-and-rinse (ER) mode[1], in addition to their reduced number of steps which can be variable according to mode of application[2] and compatibility with different substrates. Decreased sensitivity to different degrees of moisture in enamel and dentin was also reported which even made them more popular and user friendly[3] .

Debates were reported regarding the multi-mode use of universal adhesives, and though universal adhesives' use became common due to their simplicity and flexibility which enables clinicians to decide according to cavity design the most appropriate application protocol, the bond durability of many products were inferior to the performance of two-step self-etch adhesives especially with enamel tissue, regardless of application mode[4,5].

Single Bond Universal was the first universal adhesive introduced in the market. The adhesive formula included 10-MDP monomer. This monomer has the advantage of bonding chemically with tooth forming hydroxy appetite crystals, thus improving the bond durability[6]. Universal adhesive formulas kept on improving to widen their use with various material including resin luting cements[7], in addition to various substrates with no need for additional step of surface treatment [8,9]

A main advantage of universal adhesive is their compatibility with indirect restorations due to their silane content. Upon indirect restorations cementation, hindered light penetration was reported due to increased thickness of restorations in some areas, or decreased light penetration due to high opacity of some ceramics. Consequently, low degree of convergence of adhesive in such areas accompanied by lesser bond strength values were stated. In addition, incompatibility of light activated universal adhesive with chemical and dual cured core build up materials was also reported[10,11] .Hence, the idea of dual and chemical cured universal adhesives was presented. The presence of such adhesives helped to solve the problem of incompatibility between the light activated adhesives and the chemical and dual cured resin materials.

Though chemical and dual cured adhesives helped to solve many problematic clinical situations, their performance regarding bond strength values was not properly studied. Hence, this study was carried to compare Microshear bond strength (mSBS) values of chemical cured and dual cured universal adhesives with the light cured one in both ER and SE modes in the aim to reach a conclusion for the best application strategy for each of the studied adhesives. The following null hypotheses were tested (1) the curing techniques have no influence on the bond strength of resin composite to dentin and (2) the application modes have no effect on bond strength to dentin.

MATERIALS AND METHODS

Materials

A flowable resin composite, and three types of adhesive materials were used in the study. Materials composition is listed in table 1

Methods

A total of 24 anterior bovine teeth were freshly extracted and used in this study. After extraction, teeth were thoroughly washed under tap water to remove soft tissue debris and stored in 0.1% thymol

TABLE (1): Material, composition, description , pH and lot number

Material/Manufacturer (Lot #)	Description	Composition
Filtek supreme flowable restorative (3M ESPE St.Paul, MN) Lot #: NC91529	Flowable resin composite	Silane Treated Ceramic, Substituted Dimethacrylate, BISGMA, TEGDMA, N-DIMETHYLBENZOCAINE, Diphenyliodonium Hexafluorophosphate.
Palfique universal bond (PUB) (Tokuyama Dental Copr., Japan) Lot #: 118E00	Self-etch adhesive (pH= 2.2)	**Bond A:** Phosphoric acid monomer, Bis-GMA, HEMA, TEGDMA MTU-6, Acetone (solvent). **Bond B:** γ-MPTES, Borate, Peroxide, Isopropyl alcohol, Acetone and Water.
One coat 7 universal (1C) **(Colten,Whaledent, AG, Switzerland) Lot #: J33228**	Self-etch adhesive (pH=2.8)	10-MDP, methacrylates, photoinitiators, methacrylated polyacrylic acid, water and ethanol
One Coat 7.0 activator (SCA) **(Colten,Whaledent, AG, Switzerland) Lot #: J67279**	Chemical Activator	Ethanol, water, activator
All-bond universal (ABU) **(Bisco,Inc, Schaumburg, Illinois, USA) Lot #: 2000007847**	Self-etch adhesive (pH= 3.2)	Bis-GMA, HEMA, MDP, initiators water, ethanol,
Ultra-etch phosphoric acid gel (Ultradent products Inc., South Jordan, Utah, USA)	Acid etch	35% phosphoric acid

for no longer than one month. Teeth were divided into four main groups according to the adhesive used (PUB, 1C, 1C +SCA and ABU) with six teeth for each group. Each group was subdivided into two subgroups (three teeth) according to the application mode used (ER, SE). Teeth were then sectioned longitudinally in a mesio-distal direction to obtain three dentin slices from each tooth. Each slice obtained five polyethylene tubes to have a total number of 15 microshear bond specimens per group (n=15).

The incisal half of each tooth was eliminated, the labial surface of the cervical half was ground under water using #180 SiC paper to expose an area of nearly 10 mm diameter of flat dentin. The roots were cut off at the cervical line and the pulp was extirpated using H-File. Pulp chambers were cleaned and blocked using sterile cotton pieces to prevent the penetration of acrylic resin material.

A three-quarter inch in diameter Polyvinyl chloride rings (PVC rings) of 1cm height was fixed over a glass slab using double faced adhesive. With the labial dentin facing downwards, the tooth was placed in the center of the tube. A mix of cold cure acrylic resin (Acrostone, Egypt) was poured inside the tube till it became flushed with the upper rim of the tube. To decrease polymerization heat, the whole assembly was placed in tap water. After setting, each specimen was wet ground over #180 SiC paper to remove excess acrylic resin material, if presented. Wet grounding using #600 SiC for 30 seconds was done to create a smear layer.

In each adhesive strategy, bonding procedure was implemented following the manufacturer's instructions. For the ER groups, the bonding procedure was preceded with dentin etching for 15 seconds using 37% phosphoric acid etchant (Ultradent) followed by rinsing for 15 seconds, followed by blot drying using paper pellet.

For PUB in SE mode, mixing a drop from bond A and a drop from bond B was done, followed by adhesive was application on the dentin surface and gentle dryness with oil-free compressed air till no movement of adhesive was visible. For (1C) in SE mode, the bottle was shaken well, one drop of the adhesives was dispensed, applied, and rubbed to the dentin surface for 20 sec using micro brush. Gentle air dryness for 5 seconds followed. For (1C +SCA) specimens, a drop of One Coat 7.0 activator and a drop One Coat 7 universal bond were mixed into the mixing well before application to the dentine surface followed by the same protocol steps previously mentioned for (1C). For ABU specimens in SE mode, two separate coats of adhesives were scrubbed to the surface using micro brush for 10-15 sec each. The coats were applied successively with no light curing between them. Solvent evaporation followed by drying with oil free compressed air for at least 10 sec and until no visible adhesive movement.

Before adhesive curing, a polyethylene tube of internal diameter 0.9 mm and 1mm height was located over the uncured adhesive then light curing was performed, except for PUB, the adhesive was left to cure with no light curing. Light curing was performed using LED curing unit (Elipar, 3M ESPE, USA) 1200 mW/cm^2.

Flowable composite was injected inside each tube, covered with a polyester strip and pressed using a glass slide for five seconds so that any excess material was extruded. The glass slide was removed before curing was done. The resin composite was then light cured for ten seconds according to the manufacturer's instruction.

Each acrylic block with the specimen fixed to it, was mounted to the Universal Testing Machine (Lloyd instruments LR5, Leicester, UK). Testing for mSBS was done by using 0.2 mm orthodontic ligature wire applied around each specimen as close as possible to resin/dentin interface. Testing was run with crosshead speed of 0.5mm/min. until failure. Shear bond strength in Mega Pascal was calculated. SBS= load (Newton)/ bonded area (mm^2).

Data was represented as mean and standard deviation (SD) values. Shapiro-Wilk's test was used to test for normality, followed by Levene's test to test for Homogeneity of variances. Due to parametric data distribution and variance homogeneity, two-way ANOVA followed by Tukey's post hoc test were performed. Comparison of simple main effects was done utilizing the error term of the two-way model with p-values adjustment using Bonferroni correction. The level of significance was set at $p<0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows.

RESULTS

Results of two-way ANOVA presented in table (2), showed no significant effect for the adhesive strategy on microshear bond strength with *p*-value 0.253. On the other hand, the curing mode and the interaction between adhesive strategy and curing mode had significant effect on mSBS with *p*-value of <0.001 and 0.002 respectively.

Comparison of simple main effects presented in table (3) showed that for samples treated with ER protocol, there was significant differences between different adhesives with (1C), (1C+SCA) and ABU having significantly higher values than PUB ($p<0.05$). For samples subjected to SE protocol, there was also a significant difference with (1C) having significantly higher value than (1C +SCA) and PUB ($p<0.05$). The ABU Universal adhesive showed nonsignificant results with all groups in SE mode.

For PUB, samples treated with SE protocol had significantly higher values than ER samples (p<0.05), while for (1C +SCA) samples treated with ER had significantly higher values than SE samples (p<0.05). For other adhesives, no significant difference between different strategies was present (p>0.05). Mean and standard deviation values for mSBS in different groups were presented in figures (1) and (2).

TABLE (2): Two-way ANOVA for the effect of different adhesion strategy, curing mode and their interactions on μSBS

Parameter	**Sum of squares**	**df**	**Mean square**	**f-value**	**p-value**
Adhesive strategy	27.12	1	27.12	1.35	**0.253**
Curing mode	1505.39	3	501.8	24.9	**<0.001***
Adhesive strategy * Curing mode	358.39	3	119.46	5.93	**0.002***
Error	805.97	40	20.15		

**** statistically significant difference with significance level of (p<0.05).***

TABLE (3): Means ± Standard Deviations regarding the effect of different adhesion strategies for adhesives under study on the μSBS (MPa)

Adhesive strategy	**Micro-shear bond strength (MPa) (Mean±SD)**				**p-value**
	Palfique (PUB)	One coat 7 (1C)	One coat 7.0/DC activator (1C + SCA)	All-bond (ABU)	
ER	5.61±0.73^{B}	23.87±2.40^{A}	22.33±7.60^{A}	22.36±5.23^{A}	**<0.001***
SE	11.99±1.46^{B}	24.28±5.53^{A}	14.24±4.88^{B}	17.64±3.64^{AB}	**<0.001***
p-value	**0.018***	**0.874**	**0.003***	**0.076**	

Different capital letters within the row indicate statistically significant difference (p<0.05). * Below each column represents significance within the same column (p<0.05)

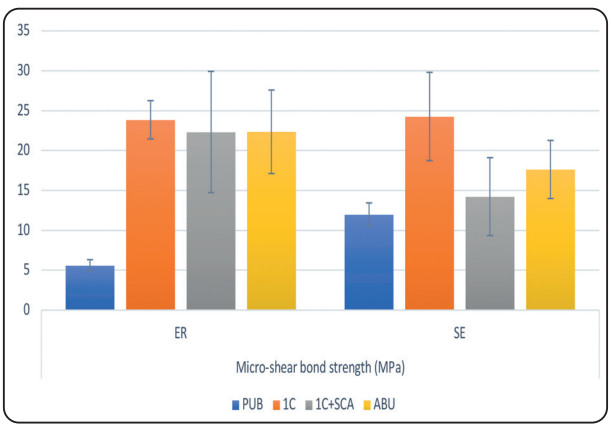

Fig. (1) Bar chart showing mean and standard deviation values of μSBS (MPa) values for different adhesive strategies

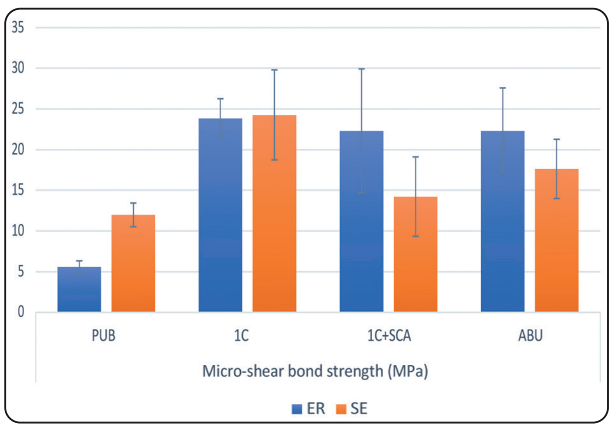

Fig. (2) Bar chart showing mean and standard deviation values of μSBS (MPa) values for different adhesives

DISCUSSION

Upon the launch of universal adhesives (multi-mode adhesives), their use expanded due to manufacturers' claim that these adhesives can be used in SE as well as ER mode in addition to their ability to be used in variety of clinical situations including direct as well as indirect restorative approaches[12]. The application mode depends on the substrate to be bonded where etch and rinse mode is mostly preferred upon bonding to enamel due to smear layer removal [13]. For dentin, ER mode was debatable due to the exposure of collagen network and increased permeability to flow of fluid, exposing the collagen network to hydrolytic and enzymatic degradation which could have detrimental effect on bond durability [14] .

Upon considering the two strategies for using multimode adhesives, bonding to dentin can be performed either by ER or SE mode, many studies were performed to evaluate the bonding efficacy of multimode adhesive in both modes, the results were quiet contradictory. Bond strength produced using universal adhesives upon application to dentin in ER mode was reported to be higher than SE mode which was consistent with the results of the present study for all adhesive types and groups used in the present study except for PUB[15,16] . Authors attributed such results to the possibility of proper dentin hybridization due to elimination of smear layer, presence of patent tubules and establishment of thick and properly formed hybrid layers and long resin tags, both of which were responsible for enhanced micromechanical interlocking reflected as higher bond strength values[17,18,19]. Using universal adhesive in SE protocol resulted in the establishment of thin hybrid layer in addition to the partial demineralization of collagen matrix, which was reflected by thinner hybrid layer, shorter and less dense resin tags and over all less monomer penetration when viewed by SEM[20,21]. On the other hand, other studies had contradictory results and suggested that the use of ER protocol showed no improvement in bond strength of multi-mode adhesive, since both hybrid layer thickness and resin tags length have no direct correlation with bond strength [22,23]. When the performance of universal adhesives on dentin substrate in SE mode was compared to two step SE adhesives, the later was reported to have higher bond durability[24] .This contradictory information concerning the performance of multi-mode adhesives while using different bonding protocols particularly with newer brands and materials categories was reported to be mainly adhesive dependent and no agreement is present on specific application protocol [25].

Most current adhesives polymerization is based on photoinitiation and production of free radicals[26]. Though photoinitiation provides the clinician with complete control over the initiation step, it proved to be problematic in areas where light delivery was compromised such as in endodontic preparations and deep cavity preparations[27]. Hence, dual cured adhesive systems were developed by adding chemical initiations as organic peroxide and aryl sulfinate salt activators to be mixed with the adhesive just before application which allowed the adhesive system to cure in the absence of light[28] .Still, the dual cured adhesive polymerization starts basically by light activation and should continue chemically by the self-cured activators. In the areas were light proved to be deficient, radical generation was spontaneous and non-controllable which was reflected by lower bond strength values[29-30] To counteract this major drawback, self-cured adhesives were developed which relayed totally on chemical polymerization through the presence of benzoyl peroxide as chemical initiator and tertiary amine as co-initiator[31]. Furthermore, many studies reported the incompatibility between dual and self-cured resin composites with simplified adhesives[32,33]. Both of which resulted in reduced bond strength values, post-operative sensitivity and microleakage. It was reported that the the pH of the adhesive plays a major role in the incompatibility issues with dual cure resin composite, where no incompatibility issues were reported with ultra-mild adhesives (pH >3) [34].

The first null hypothesis was rejected as the curing mode showed significant effect (p< 0.001) on the bond strength to dentin. According to manufacturer, the chemical composition of the activator of (1C) adhesive contains ethanol and water in addition to the activator[35], it was stated that upon mixing the activator with the adhesive, a change in solvent/ water ratio is to be expected presented as monomer dilution and disruption in components proportion of the adhesive. High solvent/water content could have a detrimental effect on solvent evaporation and adhesive polymerization, which is by default reflected on adhesive performance and bond strength results[35]. This could explain the significance difference in bond strength with or without activator when the (1C) was applied in SE mode [31]. Conversely, the use of (1C) without the addition of activator produced the highest bond strength values in all groups. This could be attributed to the fact that upon using the (1C) in ER mode, removal of the smear layer and proper hybridization within dentin occurred presented by high bond strength value as mentioned earlier [17-19]. On the other hand, using (1C) universal in SE mode presented similar bond strength values due to the presence of MDP monomer as stated by manufacturer, which can chemically bond to hydroxy apatite crystals present within dentin and produces a stable and strong bond reflected by the significantly highest bond strength values within self-etch mode of all groups within this study [6]. Though ABU contains MDP monomer, the difference between the performance of the adhesives in SE mode could be attributed to the difference in their pH. The ABU is an ultra-mild adhesive with a pH= 3.2, which could result in lesser degree of demineralization depth, hence being insufficient for effective etching for the dentin surface hence, the monomers infiltration will be hampered[36].

The second null hypothesis was partially rejected as the mode of application had a significant effect on the bond strength of both PUB and 1C+SCA (p=0.018 and 0.003 respectively). Regarding the PUB, results in SE mode which were comparable to other adhesives except for (1C), this could be attributed to scarcer resin tags formed in the hybrid layer, as reported by Campos et al. in their study, where they found that the PUB produced lower bond strength than the other tested SE adhesives used (Clearfil SE, Optibond All-in-One), though the resin tags of the PUB had deeper penetration than the other tested groups[37]. Regarding this, it could be assumed that deeper resin tags penetration associated with a pre-etching step in the ER mode as well as having a lower pH (pH=2.2) than the other groups, could have produced very deep etching, that in turn would have affected the easiness of resin infiltration, and solvent evaporation. Hence, affecting in the quality of the final hybrid layer, reflecting even lower bond strength than that reflected in the self etch mode[38,39].

CONCLUSION

Under the limitation of this study, the following conclusions could be suggested:

1. Regarding the curing modes of universal adhesives, light cured adhesives performed better than other modes when bonding to light cured resin composite.
2. Considering the mode of application, universal adhesives showed better performance with etch and rinse mode except for self cured adhesives.

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[redacted]

REFERENCES

1. Jang JH, Lee MG, Woo SU, Lee CO, Yi JK, Kim DS (2016) Comparative study of the dentin bond strength of a new universal adhesive. J Dent Mater 2016; 35: 606-12

2. De Munch Jd, 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; 84:118-32.

3. Tsujimoto A, Shimatani Y, Nojiri K, Barkmieier WW, Markham MD, Takamizawa T et al. Influence of surface wetness on bonding effectiveness of universal adhesives in etch-and-rinse mode. Eur J Oral Sci 2019; 127: 162-9

4. Tsujimoto A, Barkmeier WW, Hosoya Y, Nojiri K, Nagura Y, Takamizawa T et al. Comparison of bond fatigue durability to enamel of universal adhesives and two-step selfetch adhesives in self-etch mode. Am J Dent 2017 30, 279-84.

5. Suda S, Tsujimoto A, Barkmeier WW, Nojiri K, Nagura Y, Takamizawa T et al. Comparison of enamel bond fatigue durability between universal adhesives and two-step self-etch adhesives: effect of phosphoric acid pre-etching. Dent Mater J 2018; 37, 244-55

6. Van Meerbeek B, Yoshihara K, Yoshida Y, Mine A, De Munck J, Van Landuyt K. State of art of self-etch adhesives. Dent Mater 2011; 27:17-28.

7. Tsujimoto A, Barkmeier WW, Takamizawa T, Watanabe H, Johnson WW, Latta MA et al. Simulated localized wear of resin luting cement for universal adhesive systems with different curing mode. J Oral Sci 2018, 60, 29-36

8. Tsujimoto A, Barkmeier WW, Takamizawa T, Wilwerding T, Latta MA, Miyazaki M (2017) Interfacial characteristics and bond durability on universal adhesives to various substrates. Oper Dent 2017; 42: e59-e70,

9. Nagura Y, Tsujimoto A, Fisher NG, Baruth AG, Barkmeier WW, Takamizawa T et al. (2019) The effect of reduced application time of universal adhesives on enamel bond fatigue durability and surface morphology. Oper Dent 2019; 44: 42-53.

10. Sanares A, Itthagarun A, King N, et al. Adverse surface interactions between one-bottle light-cured adhesives and chemical-cured composites. Dent Mater. 2001;17(6):542–56.

11. Carvalho RM, Garcia FCP, E Silva SMA, et al. Critical appraisal: adhesive-composite incompatibility, part I. J Esthet Restor Dent. 2005;17(2):129–34

12. Nagarkar S, Theis-Mahon N, Perdig~ao J. Universal dental adhesives: current status, laboratory testing, and clinical performance. J Biomed Mater Res Part B Appl Biomater. 2019;107(6):2121–31

13. Perdigao J. Dentin bonding-variables related to the clinical situation and the substrate treatment. Dent Mater. 2010; 26:e24–e37..

14. Reis A, Carrilho M, Breschi L, et al. Overview of clinical alternatives to minimize the degradation of the resin-dentin bonds. Oper Dent. 2013;38(4):E1–e25.

15. Takamizawa T, Barkmeier W, Tsujimoto A, et al. Influence of different etching modes on bond strength and fatigue strength to dentin using universal adhesive systems. Dent Mater. 2016;32(2):e9–e21.

16. Munoz M, Luque-Martinez I, Malaquias P, Hass V, Reis A, Campanha N, et al. In vitro longevity of bonding properties of universal adhesives to dentin. Oper Dent 2015;40:282–92

17. Ikeda M, Tsubota K, Takamizawa T, Yoshida T, Miyazaki M, Platt J. Bonding durability of single-step adhesives to previously acid-etched dentin. Oper Dent 2008;33:702–9

18. Taschner M, Nato F, Mazzoni A, Frankenberger R, Kramer N, Di Lenarda R, et al. Role of preliminary etching for one-step self-etch adhesives. Eur J Oral Sci 2010; 118:517–24.

19. Margvelashvili M, Goracci C, Beloica M, Papacchini F, Ferrari M. In vitro evaluation of bonding effectiveness to dentin of all-in-one adhesives. J Dent 2010; 38:106–12

20. Van Landuyt K, De Munck J, Mine A, Cardoso MV, Peumans M, Van Meerbeek B. Filler debonding & subhybrid-layer failures in self-etch adhesives. J Dent Res 2010; 89:1045–50

21. Takamizawa T, Imai A, Hirokane E, et al. SEM observation of novel characteristic of the dentin bond interfaces of universal adhesives. Dent Mater. 2019;35(12):1791–1804.].

22. Wagner A, Wendler M, Petschelt A, Belli R, Lohbauer U. Bonding performance of universal adhesives in different etching modes. J Dent 2014;42:800–7.

23. Chen C, Niu L-N, Xie H, Zhang Z-Y, Zhou L-Q, Jiao K, et al. Bonding of universal adhesives to dentine-Old wine in new bottles? J Dent 2015;43:525–36

24. Tsujimoto A, Barkmeier WW, Takamizawa T, Watanabe H, Johnson WW, Latta MA et al. Comparison between universal adhesives and two-step self-etch adhesives in

terms of dentin bond fatigue durability in self-etch mode. Eur J Oral Sci 2017;125: 215-22.

25. Elkaffas A, Hamama H, Mahmoud S. Do universal adhesives promote bonding to dentin? A systematic review and meta-analysis Restor Dent Endod 2018 Jun 18;43(3):e29

26. Landuyt KL, Snauwaert J, De Munck J, Peumans M, Yoshida Y, Poitevin A, Coutinho E, Suzuki K, Lambrechts P, Van Meerbeek B. Systematic review of the chemical composition of contemporary dental adhesives. Biomaterials.2007; 28(26):3757–85.

27. Shortall AC, Harrington E, Patel HB, Lumley PJ. 2002. A pilot investigation of operator variability during intra-oral light curing. Br Dent J.2002; 193(5):276–80

28. Kwon TY, Bagheri R, Kim YK, Kim KH, Burrow MF. Cure mechanisms in materials for use in esthetic dentistry. J Investig Clin Dent. 2012 3(1):3–16.

29. Liu Y, Bai X, Liu YW, Wang Y Light-Cured Self-Etch Adhesives Undergo Hydroxyapatite-Triggered Self-Cure. J Dent Res. 2016;95(3):334-41

30. Moharam LM, Botros SA, El-Askary FS, Özcan M. Effect of polymerization protocol on the degree of conversion of photo- and dual-polymerized self-etch adhesives. J Adhes Sci Technol 2016;30:262-74.

31. Rathke A, Balz U, Muche R, Haller B. Effects of self-curing activator and curing protocol on the bond strength of composite core buildups. J Adhes Dent 2012;14:39-46.

32. Faria-e-Silva AL, Casselli DS, Lima GS, Ogliari FA, Piva E ML. Kinetics of conversion of two dual-cured adhesive systems. J Endod 2008;34:1115-8

33. Ritter AV, Ghaname E, Pimenta LAF. Dentin and enamel bond strengths of dual-cure composite luting agents used with dual-cure dental adhesives. J Dent 2009;37:59-64.

34. Michaud PL, MacKenzie A. Compatibility between dental adhesive systems and dual-polymerizing composite resins. J Prosthet Dent 2016;116:597-602

35. Gutierrez M, Sutil E, Malaquias P, et al. Effect of self-curing activators and curing protocols on adhesive properties of universal adhesives bonded to dual-cured composites. Dent Mater. 2017;33(7):775–787.].

36. Nunes TG, Erhardt MC, Toledano M OR. One-step self etching adhesive polymerization: Influence of a self-curing activator. J Dent 2009;37:616-21.

37. In-Su Lee, Sung-Ae Son, Bock Hur, Yong-Hoon Kwon, Jeong-Kil Park. The effect of additional etching and curing mechanism of composite resin on the dentin bond strength. J Adv Prosthodont;2013 Nov;5(4):479-84.

38. Campos V, Taquea L, Gomes G, et al . Evaluation of the bond strength at the resin-dentin interface using self-etching adhesive systems containing different functional monomers . Braz J Develop. 2020:6 (12);103635-46

39. Hashimoto M, Ohno H, Kaga M, Sano H, Tay FR, Oguchi H, Araki Y, & Kubota M. Over-etching effects on micro-tensile bond strength and failure patterns for two dentin bonding systems Journal of Dentistry ;2002: 30(2-3) 99-105.

40. Hashimoto M, Ohno H, Sano H, Kaga M, & Oguchi H. In vitro degradation of resin-dentin bonds analyzed by microtensile bond test, scanning and transmission electron microscopy Biomaterials; 2003: 24(21) 3795-803.