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Impact of Rubbing and Waiting Technique of a Universal Adhesive System on Shear Bond Strength of Orthodontic Brackets: A Comparative Analysis

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Abstract

Background: One important factor in orthodontics to consider is the bracket's bonding strength to the teeth substrate. This study's objective is to see how the rubbing and waiting approach of a universal adhesive system affects the shear bond strength and adhesive remnant index (ARI) of orthodontic brackets.

Materials and Methods: This was an experimental study (in vitro). Fifty newly extracted human maxillary first premolars were divided into five groups of 10 teeth each. The universal adhesive was applied on the buccal surface with 20 seconds of rubbing followed by 0, 5, 10, 15, or 20 seconds of waiting protocol according to their group. The teeth were set into blocks of acrylic resin, and the shear bond strength was tested. Afterwards, ARI was assessed. Statistical analyses were performed using the one-way analysis of variance and Tukey HSD post hoc. In addition to the Kruskal-Wallis test.

Results: One-way ANOVA showed significant differences (p=0.000) between the groups. The maximum shear bond strength was for group 5 (18.93 ± 2.82), with significant differences from group 1 (p= 0.000) and group 2 (p= 0.006). The minimum bond strength was for group 1 (11.09 ± 1.50), with significant differences from all the other groups. ARI scores revealed no significant differences between the groups (p= 0.406).

Conclusion: By allowing for adequate solvent evaporation and monomer infiltration—both of which are essential for the clinical outcome of orthodontic treatment—extending the waiting period improves the shear bond strength. The ARI was not significantly impacted by waiting time.

Keywords: Orthodontics; Shear bond strength; Universal Adhesive.

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Introduction

Fixed appliances are among the most important orthodontic tools used to give patients more aesthetically beautiful and appealing smiles, which enhances their function and self-image [1]. In fixed orthodontic mechanics, orthodontic brackets are the most crucial passive components that transfer the force generated by the force elements to the teeth [2].

One key objective of fixed orthodontic therapy is creating a suitable bond between orthodontic brackets and tooth surfaces. The bond must be sufficiently robust to withstand the forces that arise during treatment and permit bracket take-off after therapy without causing harm to the tooth enamel [3]. Orthodontic bond strength depends on a variety of factors. regarding the materials, details are provided about the enamel etching technique, bracket layout, and kind of adhesive agent; regarding the teeth, details are provided on the type of tooth and fluorosis; regarding the surroundings, details are provided about the moisture, saliva, and blood contamination [4-6].

Fixed appliance attachments should be firmly bonded to enamel surfaces to resist various events in the oral environments. Frequent debonding of orthodontic brackets leads to therapy interruption and lengthens treatment duration which causes discomfort for orthodontists and their patients [7]. Over the years, research has been done on direct bracket bonding to dental enamel. In an effort to enhance and achieve sufficient bond strength in orthodontics, evaluations of bonding systems and various enamel surface preparation techniques have been carried out [8-10].

Adhesive systems referred to as "universal" or "multimode" were introduced into the market. These materials exhibited a less aggressive pH level of 2 to 3 and accomplished adhesion through the use of functional monomers [11]. These substances may be applied to the substrate with or without prior etching [12,13]. Universal adhesives differ from standard one-step self-adhesives as they contain functional phosphate and/or carboxylate monomers. Several of these functional monomers can initiate chemical bonding with calcium in hydroxyapatites [14,15].

The universal adhesive was successfully employed for bonding orthodontic brackets, especially with etching mode [16-18].

This study aims to evaluate the impact of the rubbing and waiting technique of a universal adhesive system on the shear bond strength and the adhesive remnant index of orthodontic brackets.

Material and Methods

Specimen Collection and Preparation

For this experimental study, 50 newly extracted human maxillary first premolars were collected from three orthodontic clinics. Collected from healthy 15–30-year-old donors their teeth needed to be extracted as a part of orthodontic treatment plans. Donors provided written agreements for the use of extracted data.

The teeth sample had to meet certain requirements to be included: no apparent decalcification, cavities, cracks, hypoplastic areas, or restorations (the teeth were checked using a light curing unit) [19].

The teeth were cleared of debris and preserved in a closed container with normal saline at room temperature (220±3). The normal saline was regularly replaced to prevent bacterial development until the bonding procedure.

Before the bonding procedure, all teeth' buccal surfaces were cleaned and given a 20-second polish with non-fluoridated pumice. Before mounting, teeth were irrigated with a water spray for ten seconds and then dried with three air syringes for ten seconds.

Mounting Technique

To improve the teeth's retention inside the acrylic blocks, a big fissure bur was utilized to create retentive grooves that serrated every tooth. Afterward, the teeth were positioned vertically in a self-cure acrylic mounting, exposing the crown and directing the buccal surface to run parallel to the surveyor analyzing rod. This resulted in the application of force at a 90^0 angle to the bracket-tooth contact.

Specimen Grouping and Bonding Technique

The buccal surfaces of the mounted specimens were etched for 20 seconds using phosphoric acid gel (37%) (Ortho-Technology; Fl/USA) followed by water rinsing and drying [20].

Following that, the teeth were divided into five groups randomly according to the bonding technique with ten teeth per group (Figure 1).

Group 1: The adhesive (3M™ Scotchbond™ Universal Adhesive) was applied on the buccal surface with 20 seconds of rubbing, air drying for five seconds, and 10 seconds of curing utilizing LED curing light Valo Ortho (Ultradent, UT). This protocol was according to the manufacturer's instructions.

Group 2: The adhesive was put on the buccal surface with 20 seconds of rubbing, waiting for 5 seconds, 5

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seconds of air drying, and 10 seconds of curing.

Group 3: The adhesive was put on the buccal surface with 20 seconds of rubbing, waiting for 10 seconds, 5 seconds of air drying, and 10 seconds of curing.

Group 4: The adhesive was put on the buccal surface with 20 seconds of rubbing, waiting for 15 seconds, 5 seconds of air drying, and 10 seconds of curing.

Group 5: The adhesive was put on the buccal surface with 20 seconds of rubbing, waiting for 20 seconds, 5 seconds of air drying, and 10 seconds of curing.

Following that, 50 Maxillary first premolar stainless-steel brackets (Dentarum company, Ispringen, Germany) were attached to the teeth using orthodontic adhesive paste (Transbond XT, 3M). The bracket was then carefully positioned on the tooth using the least force possible and pushed firmly to ensure precise positioning. Next, use a sharp scalar to remove any leftover adhesive paste that may have flown out from behind the bracket.

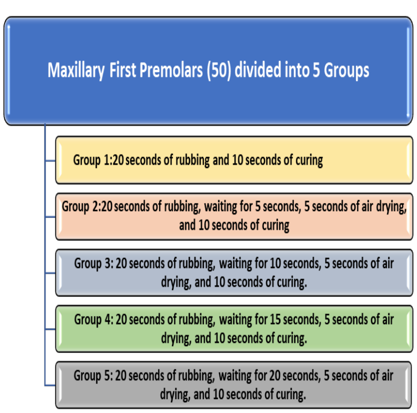

Figure 1. A diagram displaying the specimen grouping and sample size.

Shear Bond Strength Experiment

A universal testing machine (model 4411; Instron, USA) was employed to measure the force required to debond the brackets (Figure 2). The preparation of the specimens involved positioning them in acrylic resin with brackets orthogonal to the shear blade. All five experimental groups underwent a shear bond strength test, wherein the active shear blade tip was positioned on the upper part of the bracket base (Figure 3). The debonding force was applied to the bracket-tooth interface using a blade operating at a crosshead velocity of 0.5 mm/minute [21].

The measurements were obtained in kilogram-force (kg), converted to Newton (N), and the shear bond strength was estimated by dividing the amount of force by the bracket surface area. The bracket base's average surface area was 14 mm2, which allowed for the measurement of the shear bond strength in MPa.

Figure 2. Universal testing machine.

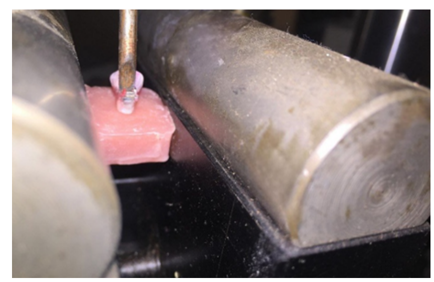

Figure 3. Shear bond experiment.

Adhesive Remnant Index Evaluation

After the debonding process, each tooth surface and the bracket base were evaluated by a stereomicroscope (Olympus, Tokyo, Japan) with an X20 magnification for evaluation of the adhesive remnant index (ARI) (Figure 4), based on the ARI scores (Table 1) [17].

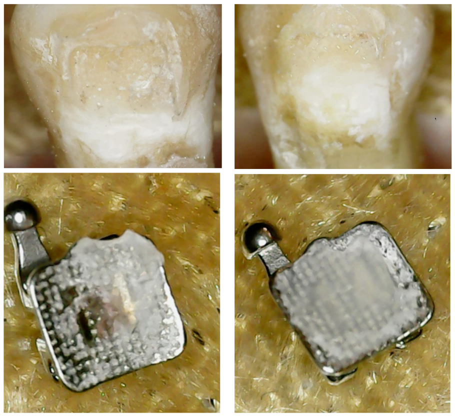

Figure 4. Microscopic evaluation of the Adhesive Remnant Index.

Table 1: Scores for the Adhesive Remnant Index.

Score 0: Indicates that no adhesive remains attached to the enamel.
Score 1: Less than ½ of the adhesive remains attached to the enamel.
Score 2: More than ½ of the adhesive remains attached to the enamel.
Score 3: The whole adhesive remains attached to the enamel.

Statistical Analyses

The statistical analyses were conducted utilizing SPSS version 26. Mean, minimum, maximum, standard deviation, and standard error were employed to evaluate the data. Shapiro-Wilk and Levene's tests, respectively, were used to screen the data for homogeneity and normal distribution. Inferential statistics utilize a 95% confidence interval. A p-value was deemed statistically significant if it was less than 0.05. As the data of shear bond revealed a normal distribution according to the Shapiro-Wilk test, One-way ANOVA and Tukey HSD post hoc multi-comparison test were used to test if there were significant differences between groups. Since the data was not continuous and did not follow a normal distribution, the ARI scores were examined by applying the Kruskal-Wallis test.

Results

The results of descriptive statistics included Min, Max, M, SD, SE, and Shapiro-Wilk test values of shear bond strength for all studied groups demonstrated in Table (2). The data were considered to satisfy the normality criteria within the 5% significance level based on the Shapiro-Wilk test, which found that the P value for all groups was greater than the significance level of 0.05. Levene's test indicated that the data were homogeneous. One-way ANOVA revealed significant differences (p=0.000) between the groups (Table 3).

The highest shear bond strength was for group 5 (18.93 ± 2.82), with significant differences from group 1 (p= 0.000) and group 2 (p= 0.006). The lowest bond strength was for group 1 (11.09 ± 1.50), with significant differences from all the other groups. Group 2 differs considerably from all other groups, but not significantly from Group 3 (p= 0.195) (Table 4). The ARI score variation for each of the five groups is shown in Table (5). The statistical examination of the ARI scores with the Kruskal-Wallis test showed no significant differences between the groups (p= 0.406).

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Table 2. Descriptive data of shear bond strength (MPa) for all groups.

Groups	N	Min	Max	Mean	SD	SE	Shapiro-Wilk test (P-value)
Group 1	10	8.99	13.30	11.09	1.50	0.47	0.487
Group 2	10	11.99	17.80	15.16	1.96	0.62	0.426
Group 3	10	14.00	22.00	17.44	2.33	0.73	0.891
Group 4	10	15.30	24.00	18.75	2.67	0.84	0.491
Group 5	10	14.56	23.80	18.93	2.82	0.89	0.718

Table 3. One-way ANOVA test of shear bond strength of all groups.

	Sum of Squares	df	Mean Square	F	p-value
Between Groups	426.836	4	106.709	19.959	0.000
Within Groups	240.593	45	5.347		
Total	667.428	49			

Table 4. Tukey HSD post hoc multiple comparison test of shear bond strength of all groups.

Groups		Mean Difference	SE	Sig.	95% Confidence Interval	
					Lower bound	Upper bound
Group 1	Group 2	-4.067*	1.03	0.003	-7.00	-1.12
	Group 3	-6.351*	1.03	0.000	-9.28	-3.41
	Group 4	-7.662*	1.03	0.000	-10.60	-4.72
	Group 5	-7.841*	1.03	0.000	-10.77	-4.90
Group 2	Group 1	4.067*	1.03	0.003	1.12	7.00
	Group 3	-2.284	1.03	0.195	-5.22	0.65
	Group 4	-3.595*	1.03	0.010	-6.53	-0.65
	Group 5	-3.774*	1.03	0.006	-6.71	-0.83
Group 3	Group 1	6.351*	1.03	0.000	3.41	9.28
	Group 2	2.284	1.03	0.195	-0.65	5.22
	Group 4	-1.311	1.03	0.712	-4.24	1.62
	Group 5	-1.490	1.03	0.605	-4.42	1.44
Group 4	Group 1	7.662*	1.03	0.000	4.72	10.60
	Group 2	3.595*	1.03	0.010	0.65	6.53
	Group 3	1.311	1.03	0.712	-1.62	4.24
	Group 5	-0.179	1.03	1.000	-3.11	2.75
Group 5	Group 1	7.841*	1.03	0.000	4.90	10.77
	Group 2	3.774*	1.03	0.006	0.83	6.71
	Group 3	1.490	1.03	0.605	-1.44	4.42
	Group 4	0.179	1.03	1.000	-2.75	3.11

Table 5. Scores for each group of the adhesive remnant index (ARI).

Groups	Score 0	Score 1	Score 2	Score 3	P-value
Group 1	2	4	2	2	0.406
Group 2	2	5	3	0	
Group 3	1	4	5	0	
Group 4	0	6	3	1	
Group 5	1	6	3	0	

Discussion

One advantage of the self-etching adhesive system is that it requires fewer stages and lowers the possibility of mistakes during the adhesive method [22]. The methacrylate phosphoric acid esters found in these adhesive systems are typically produced from phosphoric acid and demineralize the surface of the tooth by removing calcium ions [23,24]. One important factor to consider while evaluating an adhesive's efficacy is its bond strength. The adhesive strength between the two substrates is assessed using the shear bond strength test. The load that a material can withstand in a direction parallel to its face is measured by the shear bond strength test [25]. the adhesion strength can be affected by: The chemical makeup of the adhesive, light-curing apparatus, acid content, and variations in the experimental methodology [26-28]. Even though two-step complete etch bonding techniques can yield high initial resin–dentin bond strength values, they still undergo substantial decline after in vitro aging [29].

Because of the hydrophilic nature of the polymer inside the hybrid layer that promotes water sorption and increases permeability, it is vulnerable to hydrolytic deterioration [30,31]. With time, the adhesive-formed hybrid layer could deteriorate because of an increase in water absorption and a loss of collagen fiber cross bands, weakening the bond between the surfaces. This time frame could range from six months to three to five years [26,32]. In addition, research revealed that insufficient resin monomer infiltration resulted in a significant number of exposed collagen fibrils at the hybrid layer [29]. The dentin-restorative material's connection is weakened when the collagen fibrils are targeted by cysteine cathepsins and matrix metalloproteinases (MMPs) [33]. Current studies established and highlighted the role of MMPs and cysteine cathepsins on the degradation of dentin bonding after using both total-etch bonding systems and self-etch [34-36].

In order to overcome the complex nature of dentin, researchers have proposed a number of modifications to the recommended application techniques that should make the application easier to apply and maximize infiltration. Some of these modifications include longer light exposure times for bonding resins [37], multiple adhesive coatings with delayed polymerization, adhesive rubbing, and increased application times for primers and bonding resins [38, 39]. It doesn't seem to be entirely true that self-etch bonding solutions can penetrate along all demineralized dentin [34,35]. If the bonding resin is applied for a longer period of time, there will be a longer period of uninterrupted waiting before light curing. It was anticipated that this amount of waiting time would help with the evaporation of leftover solvents and unbound water [37].

Additionally, this approach change would facilitate the creation of a strongly cross-linked polymer and aid in the decrease of nanopores. As a consequence, the resin–dentin hybrid layer that is produced would be of higher quality, stronger bonds, and more resistant to deterioration [36]. The active application of the substance by rubbing has already been discussed concerning the application of resin to dentin and enamel. The main objectives are to enhance the adhesive-substrate contact surface and promote solvent evaporation [27,40].

The result showed highest shear bond strength was for group 5 in which the waiting time extended to 20 seconds with significant differences from other groups with less waiting time. The lowest bond strength was for group 1 which included waiting for 5 seconds only. So, the result declared that increased waiting time of bonding before curing can increase the bonding strength. Waiting time permits for solvent evaporation and better infiltration of monomer. different solvents, like: ethanol, water, or acetone, are included in the universal adhesive system to aid in the adhesive's transfer to the enamel. To prevent residual solvent from weakening the adhesive layer and interfering with the polymerization process, proper solvent evaporation is essential.

If there is not enough waiting time before light curing, the residual solvent may get trapped in the adhesive layer, which can cause voids and weaker bonding. Depth of monomer penetration is more likely when the adhesive has enough time to interact with the enamel. Additionally, it provides time for the adhesive to level out and create a consistent layer, which is essential for guaranteeing proper mechanical stability and polymerization.

It has been shown in several earlier investigations that the quick curing of bonding resin, without a waiting interval for the resin monomers to permeate into the etched dentin formed by total-etch bonding methods, is only partially effective. Similarly, it doesn't seem to be entirely true that Self-etch bonding techniques can penetrate along all demineralized dentin [34]. Marchesi et al. (2014) found that a short waiting period between the application of adhesive and curing could weaken the binding. For sufficient solvent evaporation and adhesive contact with the substrate, the authors advised waiting for at least 10 seconds [35]. Studies reveal that using a rubbing motion when applying adhesive enhances the orthodontic brackets' shear bond strength (SBS). Rubbing improves micromechanical retention by facilitating the entry of sticky monomers into the enamel. Furthermore, improved contact with the smear layer is achieved through active application, especially in self-etch systems, which is essential for forging a robust adhesive interface [13]. In contrast to passive applications, active adhesive system applications greatly increased binding strengths, according to a study by Papadogiannis et al. (2019). The results of the investigation demonstrated a correlation between improved adhesive penetration and higher SBS, which strengthened the binding between the enamel surface and orthodontic brackets [41]. According to a study by Hanabusa et al. (2012), the most dependable orthodontic bonding procedure produced the highest SBS values when a universal adhesive system was applied using both active application and a waiting period prior to curing [13].

Regarding the adhesive remnant system (ARI), the result cleared that increasing the waiting time had no effect on the ARI scores and

The groups did not differ significantly from one another. This result was approved by the quantities of adhesive left on the enamel surfaces did not significantly increase with longer application times or more agitation of the self-etching primer, according to Protásio et al. (2016). These findings, along with those of a different study, imply that longer application times and more agitation should not result in a higher risk of enamel fracture or require more time for tooth clean-up following deboning [24,42].

Conclusion

Increasing the waiting time enhances the shear bond strength by allowing for proper solvent evaporation and monomer infiltration, which is critical for clinical success in orthodontic treatment. Waiting time did not produce a significant effect on the ARI.

Practical Implications in Orthodontics

Combining rubbing and waiting techniques can be a standard practice in orthodontics, particularly when using universal adhesive systems. Orthodontic brackets need to withstand substantial forces, and a strong, durable bond is crucial for treatment efficacy and the longevity of the bond.

Availability of Data

This article contains the data used to support the study's conclusions.

Conflicts of Interest

According to the authors, there are no conflicts of interest.

References

1. de Almeida, A.B., I.C.G. Leite, and G.A. da Silva, Brazilian adolescents' perception of the orthodontic appliance: A qualitative study. American Journal of Orthodontics and Dentofacial Orthopedics, 2019. 155(4): p. 490-497.
2. Çiçek, O. and N. Özkalaycı, Orthodontic Brackets; Part II. J. Int. Dent. Sci, 2018. 4: p. 134-140.
3. Trakinienė, G., et al., Impact of fluorosis on the tensile bond strength of metal brackets and the prevalence of enamel microcracks. Scientific reports, 2019. 9(1): p. 5957.
4. Alzainal, A.H., et al., Orthodontic bonding: review of the literature. International Journal of Dentistry, 2020. 2020(1): p. 8874909.
5. Bakhadher, W., et al., Factors affecting the shear bond strength of orthodontic brackets–a review of in vitro studies. Acta medica, 2015. 58(2): p. 43-48.
6. Khan, H., et al., Bracket failure in orthodontic patients: the incidence and the influence of different factors. BioMed Research International, 2022. 2022(1): p. 5128870.
7. Salama, F., et al., Shear bond strength of new and rebonded orthodontic brackets to the enamel surfaces. Journal of orthodontic science, 2018. 7(1): p. 12.
8. Elnafar, A.A., M.K. Alam, and R. Hasan, The impact of surface preparation on shear bond strength of metallic orthodontic brackets bonded with a resin-modified glass ionomer cement. Journal of orthodontics, 2014. 41(3): p. 201-207.
9. Pereira, T.B.J., et al., Effects of enamel deproteinization on bracket bonding with conventional and resin-modified glass ionomer cements. The European Journal of Orthodontics, 2013. 35(4): p. 442-446.
10. Pithon, M.M., et al., Evaluation of the shear bond strength of two composites bonded to conditioned surface with self-etching primer. Dental Press Journal of Orthodontics, 2011. 16: p. 94-99.
11. Van Meerbeek, B., et al., State of the art of self-etch adhesives. Dental materials, 2011. 27(1): p. 17-28.
12. Chen, C., et al., Bonding of universal adhesives to dentine–Old wine in new bottles? Journal of dentistry, 2015. 43(5): p. 525-536.
13. Hanabusa, M., et al., Bonding effectiveness of a new 'multi-mode'adhesive to enamel and dentine. Journal of dentistry, 2012. 40(6): p. 475-484.

14. Yoshida, Y., et al., Adhesion to and decalcification of hydroxyapatite by carboxylic acids. Journal of dental research, 2001. 80(6): p. 1565-1569.
15. Yoshihara, K., et al., Adhesive interfacial interaction affected by different carbon-chain monomers. Dental Materials, 2013. 29(8): p. 888-897.
16. Proença, M.A.M., et al., Shear Strength of Brackets Bonded with Universal Adhesive Containing 10-MDP after 20,000 Thermal Cycles. International Journal of Dentistry, 2020. 2020(1): p. 4265601.
17. Shafiei, F., et al., Comparison of shear bond strength of orthodontic brackets bonded with a universal adhesive using different etching methods. Dental Press Journal of Orthodontics, 2019. 24: p. 33. e1-33. e8.
18. Goracci, C., et al., Bracket bonding to all-ceramic materials with universal adhesives. Materials, 2022. 15(3): p. 1245.
19. Shaik, J.A., et al., In vitro evaluation of shear bond strength of orthodontic brackets bonded with different adhesives. Contemporary Clinical Dentistry, 2018. 9(2): p. 289-292.
20. Alavi, S. and F. Gharibpour, Effect of universal adhesive on shear bond strength of metal bracket to enamel and dental amalgam. Pakistan Journal of Medical and Health Sciences, 2021. 15: p. 1765-72.
21. Bucur, S.M., D. Cocoș, and A. Saghin, Bond strength of three adhesive systems used for bonding orthodontic brackets. Romanian Journal of Oral Rehabilitation, 2020. 12(1): p. 162-7.
22. Pashley, D.H., et al., State of the art etch-and-rinse adhesives. Dental materials, 2011. 27(1): p. 1-16.
23. Ostby, A.W., et al., Influence of self-etchant application time on bracket shear bond strength. The Angle Orthodontist, 2007. 77(5): p. 885-889.
24. Protásio, M.F., et al., Effects of application mode of self-etching primer on shear bond strength of orthodontic brackets. Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial, 2016. 57(1): p. 9-13.
25. Yesilyurt, C. and B. Bulucu, Bond strength of total-etch and self-etch dentin adhesive systems on peripheral and central dentinal tissue: a microtensile bond strength test. J Contemp Dent Pract, 2006. 7(2): p. 26-36.
26. Triani, F., et al., Universal adhesives: evaluation of the relationship between bond strength and application strategies—a systematic review and meta-analyses. Coatings, 2022. 12(10): p. 1501.
27. Kharouf, N., et al., Does etching of the enamel with the rubbing technique promote the bond strength of a universal adhesive system? The journal of contemporary dental practice, 2020. 21(10).
28. Reicheneder, C.A., et al., Shear and tensile bond strength comparison of various contemporary orthodontic adhesive systems: an in-vitro study. American Journal of Orthodontics and Dentofacial Orthopedics, 2009. 135(4): p. 422. e1-422. e6.
29. Breschi, L., et al., Dental adhesion review: aging and stability of the bonded interface. Dental materials, 2008. 24(1): p. 90-101.
30. King, N.M., et al., Effect of resin hydrophilicity on water-vapour permeability of dental adhesive films. European journal of oral sciences, 2005. 113(5): p. 436-442.
31. Ito, S., et al., Water sorption/solubility of self-etching dentin bonding agents. Dental Materials, 2010. 26(7): p. 617-626.
32. Sirisha, K., et al., Validity of bond strength tests: A critical review-Part II. Journal of Conservative Dentistry and Endodontics, 2014. 17(5): p. 420-426.
33. Carrilho, M., et al., In vivo preservation of the hybrid layer by chlorhexidine. Journal of dental research, 2007. 86(6): p. 529-533.

34. Mazzoni, A., et al., Effects of etch-and-rinse and self-etch adhesives on dentin MMP-2 and MMP-9. Journal of dental research, 2013. 92(1): p. 82-86.

35. Marchesi, G., et al., Adhesive performance of a multi-mode adhesive system: 1-year in vitro study. Journal of dentistry, 2014. 42(5): p. 603-612.

36. El-Malky, W. and K. Abdelaziz, The effect of pre-curing waiting time of different bonding resins on micro-tensile bond strength to dentin. Tanta Dental Journal, 2015. 12(2): p. 99-110.

37. El-Din, A., Effect of changing application times on adhesive systems bond strengths. American Journal of Dentistry, 2002. 15(5): p. 321-324.

38. de Carvalho Cardoso, P., et al., Effect of prolonged application times on resin-dentin bond strengths. Journal of Adhesive Dentistry, 2005. 7(2).

39. Dal-Bianco, K., et al., Effects of moisture degree and rubbing action on the immediate resin–dentin bond strength. Dental Materials, 2006. 22(12): p. 1150-1156.

40. Caneppele, T.M.F., et al., Effects of surface hydration state and application method on the bond strength of self-etching adhesives to cut enamel. Journal of Adhesive Dentistry, 2012. 14(1).

41. Papadogiannis, D., et al., Universal adhesives: setting characteristics and reactivity with dentin. Materials, 2019. 12(10): p. 1720.

42. Iijima, M., et al., Effects of application time and agitation for bonding orthodontic brackets with two self-etching primer systems. Dental materials journal, 2009. 28(1): p. 89-95.