Ban J Orthod and Dentofac Orthop, April 2017; Vol- 7, No. 1 & 2, p 20-26

Bond Strength Comparison of Orthodontic Bonding Systems: A Systematic Review

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ABSTRACT

As a means of regular practice in orthodontics and aesthetic dentistry, resin based adhesive systems are being used exclusively. Keeping up with the ever-increasing demand for aesthetic dental treatment all over the world, newer and more improved adhesive systems have been developed. However, regarding the comparison as to which bonding system performs better in clinical perspective, there is lack of existing scientific review articles. In this review, we tend to explore the conventional etch and rinse bonding system and the self-etch primer bonding system. The different tests to assess and compare bond strength between these two types of adhesives from various bibliography are discussed. The results of shear bond strength test, adhesive remnant index (ARI), enamel-adhesive interface using scanning electron microscope (SEM) and the effect of saliva contamination and time are discussed. Interestingly, each system has its strengths and weaknesses. In shear bond strength, self-etch bonding systems clearly exhibits less strength than conventional bonding systems. Resin tags into enamel surface are shorter in self-etch primer adhesives which results from milder etching to enamel compared to the conventional aid-etch and rinse adhesives. Contrarily, the irreversible changes to enamel surface is more aggressive in conventional acid-etching which states that self-etching systems are better according to the principles of minimal intervention dentistry.

Keywords: Bond strength; Conventional etch and rinse; Self-etch primer; Shear bond strength; Resin tag.

INTRODUCTION

The successful continuation of any orthodontic treatment depends largely on the uninterrupted steps including bracket placement. The basic demands for a bracket-bonding system are to obtain an acceptably high bond strength between the orthodontic brackets and enamel and a low failure rate because loose brackets delay the treatment, replacing them is inefficient, time-consuming, and wastes material. The adhesion of resin to enamel is also affected by the orthodontic force from arch-wire. Occlusal force, may also lessen the bond strength as they cause shearing force at the resin–enamel and resin–bracket interfaces [1]. For this reason, the initial bond strength of orthodontic brackets is important since many orthodontists activate appliances in the mouth at the same day of bracket bonding and the bond strength of resin adhesive increases with time due to continued polymerization of the resin under the bracket base [2].Several better adhesive systems have been developed till now, owing to the rapid advancement in technology. One well-received adhesive is that with self-etching primer due to its fewer steps, simple clinical application and reduced technique sensitivity [3]. Acidic monomers in self-etch systems simultaneously etch and prime the tooth surface. This simplified approach can provide clinically more reliable performance [4]. Still there is insufficient in-vitro as well as clinical research that can conclude on a firm note regarding the overall comparison between conventional acid-etch and self-etching bonding system. Concerns have been raised about the bonding effectiveness of different self-etch systems related to their durability [4]. At present, 4 basic bonding systems are commercially available; i) Conventional etch-rinse, ii) self-etch, iii) universal and iv) resin based glass ionomer adhesives [5]. Due to the limitations of universal bonding system, orthodontists around the globe still prefer to use conventional and self-etch adhesive systems [6]. The traditional acid-etch-&-rinse adhesives manifest much higher bond strength than any other type of adhesives. But self-etch primer has the greatest advantage of accelerating the bonding procedure by combining etching and priming into a single step [7]. They also minimize the potential for iatrogenic damage to enamel other than saving time and reducing procedural errors. Their lower etching ability is caused by a relatively higher pH as compared with phosphoric acid used in conventional etch and rinse system [7]. A substantive number of studies have been focusing on brackets, adhesive systems and enamel surface conditioning methods in recent years. Therefore, the aims of this review were to:

A. discuss the properties of these adhesive systems and provide a collective picture of their merits and demerits.

B. Compare the bond strength among conventional etch-rinse type and self-etch type primers and review their clinical performance with conventional, self-etch type and universal adhesive agents.

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SHEAR BOND STRENGTH

Shear bond strength (shear bond strength) is the most significant measure for a good orthodontic bracket bonding, as it withstands a varying range of forces during orthodontic treatment. Mohammadi et al. [1] observed the shear bond strength of chemical-cured and light-cured conventional etch and rinse bonding agent. In both cases, bond strength increased along with increasing force. The results of the experiment of Meerbeek et al. [4] indicated that the manner of preparation of enamel prior to bonding procedures significantly influenced the bonding effectiveness of both the etch & rinse and the self-etch adhesives. In a study by Yonekuraet al. [7], one conventional etch and rinse and two self-etching bonding systems were examined. The combination of thermocycling and a torsion load significantly decreased the mean SBS for the specimen bonded with the conventional etch and rinse adhesive system, which indicates that the torsion load contributed to degradation of this system. In contrast, for both self-etching adhesive systems, there was no significant difference in the mean SBS between specimens thermocycled with and without a torsion load. Iijima et al. [8] also experimented on the same bonding systems. According to them, the self-etch Transbond plus and etch-&-rinse Transbond XT showed higher average bond strength values in dry condition than the self-etch BeautyOrtho-bond. However, in wet condition, the conventional Transbond XT exhibited the least shear bond strength. It is noteworthy that orthodontic brackets and tubes are intended to be bonded to teeth with an adhesive material for a limited time only. Therefore, an appropriate bond strength would serve to ease the debonding procedure and decrease the risk of enamel fracture [8]. In the comparison between traditional and self-etching adhesives by Saleh et al. [9] it was concluded that SBS values of brackets cemented with Transbond etch-&-rinse (18.6 MPa) were significantly higher than those of the four self-etching adhesives: Esthetic cement system, Rely X, Biscem DC and Breeze. Scougall Vilchis RJ et al. [10] compared the shear bond strengths of 5 different kinds of adhesive systems and came to inference that the Transbond type, both etch-rinse and self-etch adhesives promoted higher shear bond strength values (19.0 MPa and 16.6 MPa respectively) than the Clear fill mega bond, Orthobond and AdheSE. Nakazawa et al. [11] experimented on three self-etching bonding systems ORTHOPHIA LC, BeautyOrtho Bond, Transbond SEP and one universal bonding system Super-Bond C & B (with conventional etch-&rinse technique) and found no significant difference in SBS among the three self-etching adhesives. However, the SBS of Super-Bond C&B (17.5 MPa) was significantly higher than all self-etching adhesives. Another study by Abdelnaby et al. [12] detected highest SBS of Transbond XT adhesive, with and without torsion load (11.2 MPa and 10.7 MPa respectively). In case of universal adhesive systems, there was no significant difference in SBS between convention etch-rinse and self-etch priming in dry condition but SBS decreased notably in etch-&-rinse technique after samples had been immersed in water or thermocycled [13]. Yet, Mclean et al. [14] found that acid etching the enamel significantly improved bond strengths of the universal adhesives compared to self-etching, but storage time did not significantly affect bond strengths. Katona et al. [15] tested different strengths of bonding adhesives: in shear,traditional etch-&-rinse and priming produced a stronger bond than the single-step self-etch system. Even so, when tested in tension, the conventional bond was weaker than the self-etch bond; and when tested in torsion, the bond strengths were similar. Yamamoto et al. [16] compared the SBS among conventional, self-etch and universal bonding agents on different follow-up times (5,10,60 minutes and 24 hours) and came to conclusion that all materials had the highest bond strength at 24 hours.

EFFICACY OF ETCHING

The fundamental mechanism for adhesion of bonding agent to teeth is resin penetration into the enamel surface. This is an exchange process, in which resin monomer penetrates into the etched surface of enamel and/or dentin, which micro-mechanically bond to the surface resin tags upon polymerization [4]. Sofan et al. [5] discussed the different types of adhesive agents and their ability to etch enamel surface. One of the main drawbacks from applying self-etching adhesives is their inability to etch enamel to the same depth that phosphoric acid of conventional etching does, which is why self-etch bonding causes lesser depth of etching.Iijima et al. [8] evaluated the Interface between the adhesive resin and enamel through scanning electron microscopy (SEM) to evaluate the etching depth of bonding material. SEM showed that the depth of resin penetration of self-etch bonding into intact enamel was very shallow due to mild etching effect. In comparison, the micro resin tags were longer in conventional acid etch. In addition, self-etching primers had relatively less acidic pH values while 35% phosphoric acid showed the strongest etching effect on enamel because of the acidic pH value. Also, according to Pamira et al. [17], phosphoric acid etching led to higher bond strength between the adhesive and tooth enamel.

ADHESIVE REMNANT INDEX

Adhesive remnant index is a functional measure of the strength between bonding system and the surface of enamel. It can be measured in different scalesbased on the experiment andcan be calculatedfrom the quantity of material retained on the enamel surface after debonding of the adhesive. The more residual adhesive that remains on the enamel surface after debonding, the stronger bond there is between the adhesive and enamel. Meerbeek et al. [4] experimented with one etch-&-rinse type and one self-etch type adhesive and concluded from their ARI scores that different magnitudes of bonding force had significantly different failure modes in each adhesive group. The failure area shifted from bracket-adhesive interface to the adhesive-enamel interface with heavier bonding force. ARI scores obtained from the experiment of Iijima et al. [8] of the two different types of bonding systems were analyzed, both in dry and wet conditions. They found a significant difference in wet condition. Transbond etch-&-rinse bonding agent retained no material on the

enamel surface in 91.7% of the teeth. Contrarily, both self-etch bonding system, Transbond Plus and BeautyOrtho-bond had all or more than 90% material remaining in 75% of the teeth. CougallVilchis et al. [10] reportedBeautyOrtho bond as the weakest adhesive, 51.4% of the sample of which had no residual adhesive after debonding; and 48.5% had less than half of the adhesive left on the tooth surface. On the other hand, Transbond etch-&-rinse adhesive showed the highest ARI scores: 40% of the teeth retained all adhesive with a distinct impression of the bracket mesh while 48.5% retained less than half. In the study by Hosein et al. [18] there was a significant difference in the ARI scores between etch-rinse and self-etching adhesives, with more adhesive remaining on the enamel surface in the conventional-etch group. However, another study [19] reported no significant difference between the ARI scores of self-etching and conventional adhesives, neither after 1 hour nor 24 hours.

ENAMEL SURFACE AND COLOR ALTERATION

Iijima et al. [8] measured the pH, it was 1.39 for 35% phosphoric acid, 1.85 for Transbond Plus, and 2.20 for BeautyOrtho Bond. Both self-etching primers with relatively less acidic pH values had a mild etching effect for intact enamel. Contrarily, 35% phosphoric acid showed the strongest etching effect for intact enamel as expected with its relatively more acidic pH value. Apart from clean-up methods, shorter resin tags also decrease the risk of color alteration [10]. In fact, enamel color alteration is caused not only by the residues of resin tags in enamel, but also by a host of other factors such as clean-up method (grinding and polishing) at the time of bracket removal. Study by Hosein et al. [18] suggested that enamel loss with a self-etching primer was significantly less than conventional etching with 37% phosphoric acid and the greatest enamel loss was seen after conventional etching (-1.11 to -4.57 um) and least with the use of the self-etching primer (-0.03 to -0.74 um). Based on the report of Bishara et al. [20] the lower etching abilities of self-etch bonding systems minimized the potential for iatrogenic damage to enamel. Pashley et al. [22] used three self- etching primers with different pH values in their study. It was found that the etching patterns of aprismatic enamel were dependent on the aggressiveness of the acids, but there was no correlation between the degree of aggressiveness of etchants and the bond strength of adhesives to intact enamel. Ireland et al. [23] also reported more enamel loss when teeth were etched with phosphoric acid, compared to using self-etch primer.

EFFECT OF SALIVA CONTAMINATION AND THERMOCYCLING

In the study by Iijima et al. [8], the bonding systems were evaluated by contamination with saliva. The etch-&-rinse adhesive system, Transbond XTexhibited such a significantly low shear bond strength (SBS) that this value would not be clinically acceptable. By contrast, SBS of self-etching systems were not adversely affected by saliva contamination. To simulate aging method as in clinical conditions, the most common method is thermocycling which has been widely used to investigate bracket bond strength. Interestingly, Nakazawa et al. [11] found no significant difference between the bond strength of different self-etching and etch-&-rinse adhesives (one group stored in water 24 hours and other group stored for same time followed by thermocycling 5000 times). Various clinical conditions do not permit ideal isolation of the site, so the presence of moisture is often possible when bonding in the oral cavity [24]. Zeppieri et al. [25] and Yusua et al. [26] foundthat saliva had no effect on the bond strength of the Transbond self-etching system while Schaneveldt et al. [27] reported the enamel surface. But according to Cacciafesta et al. [28] and Öztoprak et al. [29], water, saliva and blood contamination caused significant decrease in SBS of the conventional and hydrophilic primers, yet self-etching primer was least affected by saliva contamination. So, contamination of enamel with saliva after priming decreased the bond strength although it was still clinically adequate. As for universal adhesive systems, Suzuki et al. [30] showed that they were not affected by water contamination (both thermocycled group and long-time water stored group). Nevertheless, Cartas et al. [31] experimented the action of alcoholic beverage on bonding agents and detected that bonding strength varied with the solution used. In the experimental solution which imitated alcohol, universal adhesive Enlight was stronger than conventional Transbond XT while it was opposite in rum.

Researchers		Materials	Follow up period	Result (mean MPa)
Yonekara et al. [7]		Transbond XT [etch & rinse]	Thermocycling [6000 cycles] with torsion load	8.9
		Transbond Plus self-etching Primer (SEP)		8.4
		Beauty Ortho bond [SEP]		6.1
Iijima et al. [8]	Dry	Transbond XT [etch & rinse]	24 hours	9.75
		Tranbond Plus SEP		9.14
		Beauty Ortho bond [SEP]		6.74
	Wet	Transbond XT[etch and rinse]	24 hours in 37 c water	1.47
		Transbond Plus SEP		7.74
		Beauty Ortho bond [SEP]		7.62

Researchers	Materials	Follow up period	Result (mean MPa)
Saleh et al. [9]	Transbond XT [etch & rinse]	24 hours	18.6
	Esthetic cement system [SEP]		6.0
	Rely X [SEP]		6.0
	Biscem DC [SEP]		2.2
	Breeze [SEP]		8.4
ScougallVilchis et al. [10]	Transbond XT [etch & rinse]	24 hours in 37 c water	19.0
	Transbond Plus SEP		16.6
	Clearfil Mega Bond FA [SEP]		11.0
	Shofu Primer A and B [SEP]		10.1
	AdheSE[SEP]		11.8
Abdelnaby et al. [12]	Transbond XT [etch & rinse]	24 hours in 37 c water	11.2
	Rely-a-bond [etch & rinse+ universal]		8.8
	Transbond Plus SEP		7.8
	RelyXUnicem [SEP+ universal]		5.8
Rodríguez Chávez et al. [19]	Transbond MIP [etch & rinse]	24 hours in 37 c water	6.8
	Transbond Plus SEP		6.1
Iijima et al. [21]	C&B Metabond [SEP+ universal]	24 hours in 37 c water	11.6
	Transbond Plus SEP		8.8
Zeppieri et al. [25]	Dry		
	Transbond XT [etch & rinse]	24 hours	21.3
	Transbond MIP [etch & rinse]		20.7
	Transbond MIP, then wet, again Transbond MIP		13.1
	Transbond Plus SEP		13.7
	Transbond Plus SEP, then wet, again Transbond Plus SEP		13.8
	Wet		
	Transbond MIP	24 hours in 37 c water	15.0
	Transbond MIP, then wet, again Transbond MIP		14.9
	Transbond Plus SEP		12.7
	Transbond Plus SEP. then wet, again Transbond Plus SEP		13.6
Yusua et al. [26]	Transbond XT [etch & rinse]	2 years or thermocycling [6000 cycles]	9.8
	Transbond Plus SEP		9.1
	Beauty Ortho bond [SEP]		7.4
Cacciafesta et al. [28]	Dry		
	Transbond XT [etch & rinse]	24 hours	11.95
	Transbond MIP		12.76
	Transbond Plus SEP		12.29
	Wet	24 hours in 37 c water	
	Transbond XT [etch & rinse]		4.54
	Transbond MIP [etch & rinse]		8.01
	Transbond Plus SEP		10.87

*SEP: Self Etching Primer; MIP: Moisture Insensitive Primer; LC: Light Cured; LR: Lingual Retainer

Researchers	Materials	Follow up period	Result (mean MPa)
	Dry		
Öztoprak et al. [29]	Transbond XT [etch and rinse]	72 hours in 37 c water	15.28
	Transbond Plus SEP		13.76
	Assure hydrophilic primer		16.40
	Saliva contamination		
	Transbond XT [etch and rinse]		3.79
	Transbond Plus SEP		13.80
	Assure hydrophilic primer		10.66
	Blood contamination		
	Transbond XT [etch and rinse]		3.08
	Transbond Plus SEP		5.28
	Assure hydrophilic primer		6.83
		Thermocycling	
Turk et al. [33]	Transbond XT [etch and rinse]	0 cycle	18.08
		2000 cycles	17.14
		5000 cycles	16.70
		0 cycles	18.15
	Transbond Plus SEP	2000 cycles	14.50
		5000 cycles	14.68
	Aegis Ortho [SEP+ universal]		5.31
	Clearfil Protect Bond [SEP+ universal]	30 minutes	7.05
Minicket al. [34]	iBond[SEP+ universal]		3.91
	Clearfil S3 Bond [SEP+ universal]		3.80
	Transbond XT [etch and rinse]		10.05
	Aegis Ortho [SEP+ universal]		7.17
	Clearfil Protect Bond [SEP+ universal]	24 hours in 37 c water	6.09
	iBond[SEP+ universal]		3.86
	Clearfil S3 Bond [SEP+ universal]		6.60
	Transbond XT [etch and rinse]		10.11
	Transbond Plus SEP		
Turk et al. [35]	Dry	24 hours	17.61
	• saliva contamination after priming		10.94
	• saliva contamination before priming		10.05
	• saliva contamination before and after priming		9.79
	Transbond XT [etch and rinse]	30 minutes	4.2
Otsbyet al. [36]	Adper Prompt L-Pop [SEP]		5.9
	Clearfill Mega bond [SEP+ universal]		6.5
	Adper Prompt L-Pop [SEP]	48 hours in deionized water	9.62
Arhun et al. [37]	Clearfil Protect Bond [SEP+ universal]		13.85
	Transbond Plus SEP		6.39

*SEP: Self Etching Primer; MIP: Moisture Insensitive Primer; LC: Light Cured; LR: Lingual Retainer

CONCLUSION

From the discussion and comparison of all the strength tests, it can be stated that some of the strength properties showed clear difference between conventional etch-&-rinse bonding system and self-etching bonding system. The traditional adhesives exhibited much higher shear bond strength than self-etchadhesives [7,8,9,10,12,25,26,28,29,33,34,36]. It also resulted in stronger etching of enamel surface than the mild etching caused by the self-etch adhesives [5,8,17]. However, the stronger acidic pH of the conventional etching agents caused more drastic loss to enamel surface [8,18,23] which questions the appropriateness of these acids, considering minimal intervention during dental treatment procedures. Based on the adhesive remnant index (ARI) scores from different studies, it is evident that the result is significantly different in dry and wet condition. In dry condition, conventional etch-&-rinse leads to better bond strength between bond-enamel interface [4,8,10,18]. However, the same adhesive fails drastically in wet contaminated condition [8].There is also report [19] that found no difference between ARI scores of conventional and self-etch adhesives. Regarding the bond strength against water, saliva or blood contamination, there are studies in support of different results. Some studies state no significant difference in dry or wet condition [11,25,26,30]. But some studiesfound low shear bond strength of conventional and hydrophilic primer containing bonding agents, especially when contamination occurred before and/or after priming. Yetself-etching primer was least affected by saliva contamination [28,29]. So, further studies are necessary to reach an obvious result in this matter.In the reviewers' opinion, conventional acid-etch bonding agents are better in overall strength outcomes as long as the tooth surface remains dry.

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