IN-VITRO COMPARISON OF SHEAR BOND STRENGTH AND DEBONDING CHARACTERISTICS OF TWO ADHESIVE SYSTEMS

Hameedullah Jan[a], Ayesha Anwar[b], Sadia Naureen[c]

[a] BDS, D.Orthod, MCPS, FCPS (Pak), OJT (USA), Assoc Prof of Orthodontics, 28 Military Dental Centre, Lahore Cantt. Email:huj100@hotmail.com
[b,c] BDS, FCPS-II Residents in Orthodontics

ABSTRACT

Introduction: With the introduction of new orthodontic materials, it is imperative to evaluate them, both clinically and in-vitro, before recommended for daily clinical use. Shear bond testing, in-vitro, serves as a quick and effective way of testing bond strength of the orthodontic adhesives. Results enable the clinician to choose a superior and more suitable material. **Objectives:** To compare the shear bond strength and debonding characteristics of two orthodontic adhesives. **Study Design:** Quasi-Experimental **Sampling Technique:** Non Probability/ Convenience **Setting:** The study was conducted at Armed Forces Institute of Dentistry, Rawalpindi. **Materials and Methods:** 60, freshly extracted bovine incisors were divided into two groups, A and B, of thirty each. Stainless steel, metal, Roth 0.022" slot brackets were bonded to the teeth. Teeth in Group A were bonded using Transbond Plus Self Etchant Primer system, those in group B were bonded using Transbond XT system. After storage in normal saline at room temperature for 24 hours, the samples were subjected to shear bond testing. The Adhesive Remnant Index (ARI) was calculated for each bracket under magnification. The data was analyzed using the student's t-test, with the level of significance set at $p \leq 0.05$. **Results:** Mean shear bond strength for Group A was, 5.97 ±1.23MPa while for Group B was 6.56±1.23MPa. Group B showed higher Adhesive Remnant Index scores than did Group A samples. The results were statistically significant, $p<0.05$. **Conclusion**: The shear bond strength of the Self etchant primer system was significantly less than the conventional bonding agent; however, it was still within clinically acceptable limits.

Key Words: Self Etchant Primers, Shear bond strength, bovine enamel**.**

Correspondence: Dr Hameedullah Jan Assoc Prof of Orthodontics, 28 Military Dental Centre, Lahore Cantt. Email:huj100@hotmail.com

INTRODUCTION

In 1955, Buonocore introduced a technique of acid-etching. The concept of bonding resins to enamel has enjoyed applications in all fields of dentistry, including the bonding of orthodontic brackets. [1–3] Bonding of orthodontic attachments has become an accepted clinical technique, since 1970.[4,5] Consequently, several generations of adhesive systems have emerged. However, currently two major categories are of great interest. Conventional adhesive systems use three different agents: (1) an enamel conditioner, (2) a primer solution, and (3) an adhesive resin to bond orthodontic brackets to enamel. Orthodontists generally use the conventional acid-etching bonding technique to attach brackets to the enamel surface. The self-etching adhesives have recently become available which combine the functions of primer and adhesive components, not requiring a separate acid-etching step and thus eliminating the need for rinsing.[6] Enamel surface is simultaneously etched and primed for bonding thus not only reducing chair-side time but improving cost effectiveness as well.

Some studies suggest that self etchant primer (S.E.P) based adhesives achieve lower shear bond strengths (SBS) compared to conventional acid etch adhesives[7], i-e they tend to debond under lower shear stresses and yet others support the notion that an acceptable shear bond strength is achieved for both materials specially if the S.E.P was air dispersed prior to bonding the attachment.[8]

In-vivo contamination is very difficult to avoid and is a true clinical reality. Moisture contamination during bonding significantly reduces shear bond strength of the conventional system, the strength of the S.E.P system remains clinically acceptable[9]. The minimal bond strengths necessary for clinical loading ranges from, 6-8 Mega Pascal (MPa).[10] In-vitro, studies comparing the bond strengths of these materials conclude that SBS with S.E.Ps is least affected compared to brackets bonded either with the

conventional or Moisture Insensitive Primer (MIP).[11] SBS of all these materials decreases over time specially if intra-oral hygiene maintenance is inadequate as they exhibit time dependant intra-oral deterioration.[12]

Cleanup of enamel after debonding is equally important. It is desirable to return the enamel to its pretreatment condition as much as possible. [13] The ideal would be minimal enamel loss at each stage of the bonding, debonding, and enamel clean-up process and the production of an enamel surface with the same degree of roughness or smoothness as the original, untreated tooth.[14]

Some authors suggest that it is favorable for brackets to fail at their resin/bracket interface, as this makes cleanup after debonding easier, with minimal enamel damage. While others disagree, claiming that it is more desirable if the failure occurs at the resin/tooth interface so as to minimally expose the tooth to rotary instrumentation.[15]

Shear bond strength affects the adhesive remaining on the tooth surface. The higher the shear bond strength, the more the chances of the failure occurring at the bracket/adhesive interface. Conversely, if the shear bond strength is low, failure at the adhesive /tooth interface would be more likely. Though, the desirable failure interface is controversial, S.E.P based adhesives mostly show a failure at the adhesive/tooth interface.[14]

Most in-vitro studies assessing shear bond strength have been carried out on extracted human premolars.[16] This has an advantage of simulating natural tooth structure hence being close to the clinical reality if other factors such as intraoral working environment and exposure to saliva are ignored. Bovine enamel is believed to be a reliable substitute for human enamel for bond testing.[17] Despite the differences between human and bovine teeth Nakamichi[18] found that bovine enamel showed similar bonding patterns, but the mean shear bond strength for bovine enamel was less. Oesterle et al[19] determined the disparity between bond strengths achieved on bovine and human enamel and found that the bond was 21% - 44% weaker to bovine enamel than human enamel.

The aims of this study are to compare the shear bond strengths and de-bonding characteristics of brackets bonded with Self Etching Primer based and conventional Phosphoric Acid etchant based adhesive materials on bovine enamel.

The results of this study will enable the operator to choose a bonding material that best keeps enamel integrity to its pretreatment condition at the time of de-bonding, without compromising clinical bond strength.

MATERIALS AND METHODS

Bovine teeth were selected as a substrate to test bond strength of two materials, conventional etch based bonding adhesive, and a self etchant primer based bonding system. 60 freshly extracted bovine incisors were collected from various slaughter-houses after the animal was sacrificed. They were examined for surface defects. Teeth that had no surface defects, cracks or any other anomaly were included in the study. The incisors were divided into two groups of thirty each, Group A and Group B.

In order to keep calculations simple, only one type of bracket was used. In this study metal Roth 0.022" Slot lower incisor brackets (Orthocare UK Limited) were used.

Samples in Group A were bonded using the SEP system, Transbond™ Plus (3M US Unitek), according to the manufacturer's instructions. The Self etchant Primer was activated by sequentially squeezing the contents of the last chamber into the next and mixing. This was then applied to the tooth with the applicator and rubbed for three seconds. The Adhesive Transbond™XT (3M US Unitek) was applied to the bracket and placed on the tooth to be bonded, using bracket holding pliers. The bracket was fitted and the adhesive flash removed. The bracket was then light cured for 30 seconds.

Sample in group B were bonded using Transbond™XT (3M US Unitek), according to the manufacturer's instructions. The teeth were first etched with 37% o-phosphoric acid for thirty seconds and then washed followed by air drying. Primer supplied in the kit was then applied with an applicator and light cured for 5 seconds. The adhesive was then applied to the bracket and bonded to the tooth as previously describes for group A.

Both the specimens were stored in normal saline separately, for twenty four hours. They were stored at room temperature.

The samples then underwent shear bond testing in a shear load testing machine, Satec KN 500(Germany) shown in Fig (1). Shear load was applied through a wire ligature around the bracket wings, parallel to the

tooth bracket interface at a cross head speed of 1mm/min. Maximum load before bracket failure, held in the clamps, was noted in Newtons.

Bracket bonding and shear load testing were done by a single operator. Once debonded, the tooth observed by a single operator to determine the amount of material remaining on the tooth surface. The following scoring method was used,

Adhesive Remnant Index:

1. Score 0= no adhesive remaining on the tooth
2. Score 1= up to 25% adhesive remaining on tooth.
3. Score 2= up to 75% adhesive remaining on the tooth
4. Score 3=100% adhesive remaining on tooth with the impression of the bracket on the material.

Data was analyzed through SPSS version 10. Descriptive statistics, mean, range and standard deviation were calculated for each of the two test groups. Student's t test was applied to the SBS values to determine whether the groups differed significantly or not. Chi- square test was applied to the ARI scores to determine their significance. Significance was set at a probability value of .05 or less.

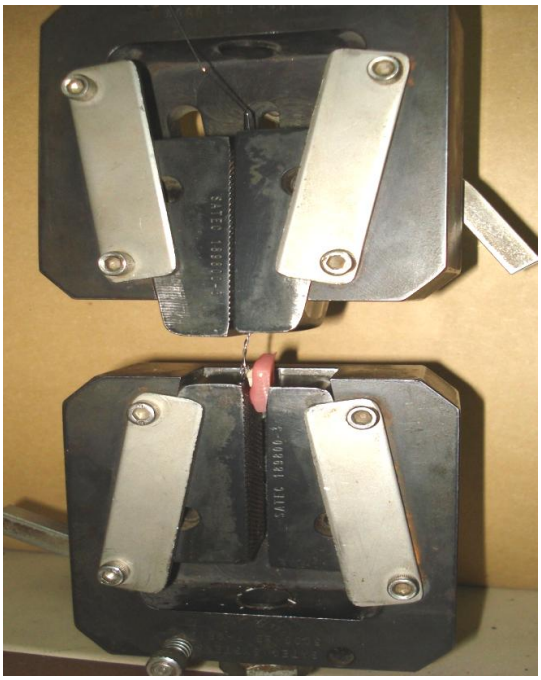

Figure 1: Specimen under shear load

RESULTS

The mean shear bond strength reported for Group A, where the brackets were bonded using the SEP system, Transbond Plus, was 5.97 MPa with a standard deviation of ±1.23MPa. The maximum value observed in this group was 7.84 MPa and the minimum value seen was 2.60 MPa. The range was 5.24 MPa. (Table 1).

Table 5:Shear bond strengths in Groups, A and B.

Group/SBS	Range	Min	Max	Mean	SD*
A	5.24	2.60	7.84	5.97	1.2340
B	3.50	5.00	8.50	6.56	.8223

The mean shear bond strength reported for Group B, in which the brackets were bonded using the Transbond XT adhesive and bonding system was 6.56 MPa with a standard deviation of ± 0.822 MPa. The maximum and minimum values observed were, 8.50MPa and 5.00 MPa with a range of 3.50MPa. (Table 1)

The mean difference between the shear bond strengths of both Groups was of statistical significance, p= 0.032.

ARI scores for both groups have been shown in the table, (Table 2).

Table 6: ARI Distribution For Groups, A and B.

		GROUP		Total	
		GROUP A	GROUP B		
ARI	0	6	2	8	ARI
	1	14	6	20	
	2	8	18	26	
	3	2	4	6	
Total		30	30	60	Total

The adhesive remnant scores for Group A showed a trend toward bond failure at the tooth adhesive interface. 6 samples (20%) displayed no adhesive remaining on the tooth, hence a score of zero. 14 samples (46.7%) had up to 25% material remaining on the tooth and were scored 1. 8 specimens (26.7%) scored 2, with up to 75% adhesive still bonded to the tooth. Whereas only 2 samples (6.7%) had all the tooth remaining on the tooth, with an ARI score of 3. (Fig 2)

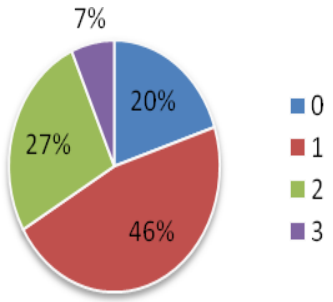

Figure 2: ARI score distribution in Group A

The adhesive remnant score for Group B failed mostly at the resin bracket interface. In comparison to Group A only 2 samples (6.7%) scored 0. 6 samples (20 %) scored 1, with up to 25% adhesive attached to the tooth. 18 (60%) specimens has up to 75% adhesive remaining on the tooth scoring, 2.4 (13.3%) teeth had all the material left on the tooth scoring 3.(Fig 3)

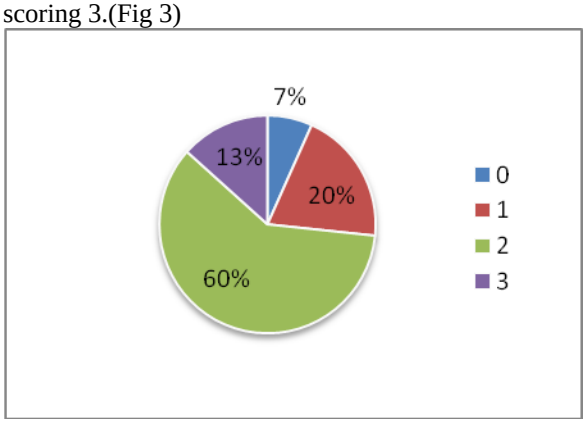

Figure 3: ARI score distribution in Group B

The debonding characteristics of both the groups were statistically significant ($p<0.05$). With Group A showing a greater tendency toward bond failure at the adhesive tooth interface and Group B at the resin bracket interface.

DISCUSSION

Evolution of material sciences demands simplification of material handling, manipulation and reduced time consumption. Over the years, numerous methods and materials have been introduced. A relatively recent advancement is the introduction of SEP systems.

Adhesion to enamel was originally conceived by Buonoucore, for improving the bond of restorative materials to dentin. It gained popularity in Orthodontics only later. Likewise, SEP system was first developed for restorative materials, when 10% maleic acid was used in place of phosphoric acid to reduce the depth of etch and reduce enamel loss.[20]

Enamel loss during acid etching has been found to depend on the acid, its dissociation constant, the concentration and the length of time it is in contact with the enamel surface. The enamel loss is typically in the region of 8.8 to 16.4 _m with 37% phosphoric acid. [21] Enamel loss, was significantly lower with self etchant primers reported in one study, where they observed the cumulative enamel loss including debonding.[22]

But reduction in enamel loss is only one of the many advantages of SEPs quoted in literature. Fewer operatory steps, reduced chair-side time and technique sensitivity are a few others. SEPs are relatively less technique sensitive as compared to the conventional bonding agents. This property can be attributed to their slight hydrophilic nature. [23]

There is controversy regarding the bond strength achieved by SEPs, but most studies agree, that even if the strength is somewhat lower, it is clinically acceptable for all orthodontic puposes.[24, 25]

In the present study the mean shear bond strength of group A samples was 5.9MPa for the teeth bonded with Transbond Plus SEP and 6.5 MPa for the conventional etch group. The results of our study, with the mean shear bond strength of group b being significantly higher than that of group A, are comparable to several studies, where a similar pattern exists.[26] In comparison to these studies the mean shear bond strengths of either group is quite less. This can be a consequence of using a bovine substrate rather than human enamel.

Results of this study were comparable to another one[17] where authors have validated bovine enamel as a suitable counterpart for human enamel. In contrast to the studies mentioned above, some authors believe that the bond strengths achieved though SEPs is not significantly different from those achieved by the conventional etch techniques.[27] There are still other studies[28, 29] which reveal that under salivary contamination SEPs reach bond strengths significantly higher than their conventionally bonded counter parts, which are much more technique

sensitive than SEPs. Even MIPs, under contaminated conditions achieve bond strengths lower than SEPs.[28] In the present study the adhesive remnant index was graded on a four unit scale, 0-3 rather than a six unit scale from 0-5. The debonding mode was significantly different for both groups. Group A showed a tendency for failure at the resin tooth interface and less adhesive remained on the tooth as a consequence. On the other hand Group B showed a mixed debonding mode, with most of the brackets failing at the bracket adhesive interface leaving a greater amount of material on the tooth. There is controversy as to which adhesive failure mode would be favorable. If one considers chair side time and iatrogenic damage from burs during post-debonding clean-up, a lower ARI score would be favorable. However if one considers the potential of cohesive failure within the enamel and its fracture during debonding, which could be more deleterious than enamel scarring through burs, higher ARI score would be preferable. The chances of enamel fractures with SEPs might be less because of its bonding modality.

In our study we applied shear loads to the brackets through wire loops. Shear blades, which apply load at the tooth/bracket interface at a particular speed, are also used. Standardization in bond testing for comparison of studies is required as the mode, and location of force application influences the results.[30] Bond testing can be carried out through tensile loads as well which yield slightly different values than shear stresses[17].

Despite much effort, there are a few drawbacks of the current study which are common to studies of similar design. This was an in-vitro study, and the results may not be applied to clinical situations with absolute confidence. We have tested the bracket under shear stresses through a wire loop and torsion and rotation in the wire may have caused variable results in every specimen which was not countered for.

In the oral cavity the brackets are subject to a variety of stresses and conditions. The adhesive is exposed to variation in temperature, bacteria and saliva. An oral environment was not attempted to be simulated and the specimens were neither subject to thermo cycling nor stored at body temperature in artificial or natural saliva.

Furthermore, we have used bovine teeth, which although acceptable counterparts[17] still yield slightly different results.

CONCLUSION

Self etchant primers are a laudable development in the field of orthodontics. The bond-up appoint is usually long and tiring for the patient. With the use of self etchant primers chair side and appointment time is reduced minimizing, patient discomfort. Reduction in operatory steps also reduces the inventory required for each appointment. Though the bond strength resulting from SEPs is significantly less, it is adequate for orthodontic purpose.

After debonding, the failure mode leaves little material on the tooth. This enables the orthodontist to spend much less time on the post de-bonding cleanup. Iatrogenic damage to enamel, from rotary instruments, is hence reduced.

Bovine teeth are a good alternative to human enamel for in-vitro bonding studies. It is readily available and a larger defect free sample can be collected at a given time.

ACKNOWLEDGEMENT:

I do appreciate the wonderful efforts being made by great Residents and Khalid hameed Marwat in the final reshaping of this article.

REFERENCES

1. Bishara SE, Laffoon JF, Vonwald L, Warren JJ. The effect of repeated bonding on the shear bond strength of different orthodontic adhesives. Am J Orthod Dentofacial Orthop. 2002; 121:521–525.
2. Newman GV, Snyder WH, Wilson CE Jr. Acrylic adhesives for bonding attachments to tooth surfaces. Angle Orthod. 1968; 38:12–18.
3. Retief DH, Dreyer CJ, Gavron G. The direct bonding of orthodontic attachments to teeth by means of an epoxy resin adhesive. Am J Orthod. 1970; 58:21–40.
4. Thanos CE, Munholland T, Caputo AA. Adhesion of meshbase direct-bonding brackets. Am J Orthod. 1979; 75:421– 430.
5. Gorelick L. Bonding metal brackets with a self-polymerizing sealant-composite: a 12-month assessment. Am J Orthod.1977; 71:542–553.
6. Gorelick L, Geiger AM, Gwinnett AJ. Incidence of white spot formation after bonding and banding. Am J Orthod. 1982; 81:93–98.
7. Cehreli ZC, Kecik D, Kocadereli I. Effect of self-etching primer and adhesive formulations on shear bond strength of

orthodontic brackets. Am J Orthod Dentofacial Orthop 2005; 127:573-9.
8. Barkmeier WW, Los SA, Triolo PT. Bond Strengths and SEM evaluation of Clearfil Liner Bond 2. Am J Dent 1995; 8:289-93.
9. Talic YF. Comparative bond strengths of five dental adhesives on Dentin. J Pak Dent Assoc 2003; 12:69-76.
10. Cacciafesta V, Sfondrini MF, Calvi D, Scribante A. Effects of fluoride application on shear bond strength of brackets bonded with a resin-modified glass-ionomer. Am J Orthod Dentofacial Orthop 2005;127:580-3
11. Sirirungrojying S, Saito K, Hayakawa T, Kasai K. Efficacy of using self-etching primer with a 4-META/MMA-TBB resin cement in bonding orthodontic brackets to human enamel and effect of saliva contamination on shear bond strength. Angle Orthod. 2004; 74:251–258
12. Awliya WY, Hassan KA. In-Vitro assessment of composite resin microhardness as affected by immersion in different beverage. J Pak Dent Assoc 2005; 14:195-9.
13. Campbell PM. Enamel surface after orthodontic bracket debonding. Angle Orthod 1995; 2:103-10.
14. Hosein I,Martyn Sherriff M, Ireland AJ. Enamel loss during bonding, debonding, and cleanup with use of a self-etching primer..Am J Orthod Dentofacial Orthop 2004;126:717-24.
15. Larmour CJ, Bateman G, Stirrups DR. An investigation into the bonding of orthodontic attachments to porcelain. Eur J Orthod 2006;28: 74–7.
16. Grubisa HS, Heo G, Raboud D, Glover KE, Major PW. An evaluation and comparison of orthodontic bracket bond strengths achieved with self etching primers. Am J Orthod Dentofacial Orthop 2004; 126:213-9.
17. Saleh F, Taymour N. Validity of using bovine teeth as a substitute for human counterparts in adhesive tests. East Mediterr Health J 2003; 9: 201-7.
18. Nakamichi I, Iwaku M, Fusayama T. Bovine teeth as possible substitutes in the adhesion test. Journal of dental research, 1983, 62:1076–81.
19. Oesterle LJ, Shellhart WC, Belanger GK. The use of bovine enamel in bonding studies. American journal of orthodontics, 1998, 113:514–9.
20. Barkmeier WW, Erickson RL. Shear bond strength of composite to enamel and dentin using Scotchbond multi-purpose. Am J Dent 1994; 7:175-9.
21. Legler LR , Retief DH, Bradley EL Effects of phosphoric acid concentration and etch duration on enamel depth of etch: an in vitro study. Am J Orthod Dentofacial Orthop 1990; 98:154-60.
22. Dorminey JC, Dunn WJ, Taloumis LJ Shear bond strength of orthodontic brackets bonded with a modified 1-step etchant-and-primer technique..Am J Orthod Dentofacial Orthop. 2003; 124:410-3.
23. Bishara SE, Ajlouni RA, Laffoon JF, Warren JJ. Effects of modifying the adhesive composition on the bond strength of orthodontic brackets. Angle Orthod. 2002; 72:464–67.
24. Bishara SE, VoWald L, Laffoon JF, Warren JJ. Effect of a self-etch primer/adhesive on the shear bond strength of orthodontic brackets Am J Orthod Dentofacial Orthop 2001; 119:621-4.
25. Davari AR, Yassaei S, Daneshkazemi AR, Yosefi MH . Effect of Different Types of Enamel Conditioners on the Bond Strength of Orthodontic Brackets. J Contemp Dent Pract 2007; 1:36-43.
26. Bishara SE, Oonsombat C, Ajlouni R, Laffoon JF. Comparison of the shear bond strength of 2 self-etch primer/adhesive systems. Am J Orthod Dentofacial Orthop. 2004;125: 348–350
27. Moriwaki Y, Kani T, Kozatani T, Tsutsumi S, Shimode N, Yamaga R. The crystallinity change of bovine enamel during maturation. Jpn J Dent Mater 1968;9:78–85
28. Zeppieri IL, Chung C-H, Mante FK. Effect of saliva on shearbond strength of an orthodontic adhesive used with moisture-insensitive and self-etching primers. Am J Orthod Dentofacial Orthop. 2003; 124:414–419.
29. Turk T, Elekdag-Turk S, Isci D, Fethiye Cakmak F, Ozkalayci N. Saliva Contamination Effect on Shear Bond Strength of Self-etching Primer with Different Debond Times. Angle Orthodontist 2007; 77:901-6.
30. Klocke A, Kahl-Nieke B. Influence of force location in orthodontic shear bond strength testing. Dent Mater 2005; 21:391–6.