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One-component self-etching primer: a seventh generation of orthodontic bonding system?

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SUMMARY The purpose of this study was to compare the bond strengths and to evaluate the debonding site using the adhesive remnant index (ARI) provided by a conventional acid-etch conditioner and a new self-etching adhesive system, Xeno IV (Dentsply Caulk).

One hundred and eighty bovine lower incisors were randomly divided into six groups ($n = 30$). In groups 1, 2, and 3, Transbond XT (3M Unitek) composite was used to bond the brackets to enamel samples conditioned with 37 per cent phosphoric acid + XT primer (3M Unitek), Xeno IV + XT primer, or Xeno IV only, respectively. In groups 4, 5, and 6, the bonding procedures were performed using Fuji Ortho LC (GC Corp.) resin-modified glass ionomer cement unconditioned, enamel conditioned with 37 per cent phosphoric acid, or Xeno IV, respectively. All samples underwent thermocycling and then shear bond strength (SBS) testing was performed using a universal testing machine (Emic DL 10.000). Analysis of variance was applied. For the *post hoc* test, the Tukey's test was used. Kruskal–Wallis and Mann–Whitney U-tests were used to assess ARI scores.

The results demonstrated no statistical differences between groups 1, 2, and 3. However, statistically significant differences were found between these samples and groups 4, 5, and 6. With regard to ARI score, the highest mean value was found in group 5 (Fuji Ortho LC + 37 per cent acid conditioning), whereas group 4 (Fuji Ortho LC + no conditioning) had the lowest SBS. Xeno IV self-etching bonding agent was able to bond orthodontic brackets in association with Transbond XT composite as well as with Fuji Ortho LC, thus maximizing bracket bonding.

Introduction

Since Buonocore (1955) introduced the acid-etching bonding technique, the concept of bonding resins to enamel has developed applications in all fields of dentistry (Attar *et al.*, 2007), including the bonding of orthodontic brackets (Bishara *et al.*, 2002). By the 1970s, bonding of orthodontic brackets had become an accepted clinical technique (Gorelick 1977; Thanos *et al.*, 1979). Bonding brackets has some advantages, including ease of placement and removal, minimal soft tissue irritation and gingival hyperplasia, and minimal danger of decalcification with loose bands, besides being more aesthetic (Boyd and Baumrind 1992).

Different materials and methods for bonding brackets are constantly being developed. Conventional adhesive systems use three different agents, an enamel conditioner, a primer solution, and an adhesive resin, in the process of bonding orthodontic brackets to enamel (Bishara *et al.*, 2004).

Advances in adhesive technology have led orthodontists to incorporate new adhesives, composite resins, and bonding techniques into their clinical practices. Self-etching primer (SEP) products, which combine acid and primer, simplify the bonding procedure, reducing chair time and avoiding the side-effects of acid etching (Sirirungrojying *et al.*, 2004). Contemporary two-step SEPS and the new one-step self-etching adhesive systems are attractive additions to the clinician's bonding armamentarium (Pashley and Tay 2001; Amra *et al.*, 2007; Bishara *et al.*, 2008).

The changes regarding different generations of bonding systems have progressed from etching enamel to conditioning dentine, smear layer treatment, and altered handling properties of adhesive systems (Schaneveldt and Foley 2002). Fourth-generation bonding systems consist of a three-step application: acid etching, use of a primer (to ensure maximum adhesion by improving monomer penetration into the etched enamel and hydrophilic dentine substrate and to improve wettability of the tooth surface), and a resin-bonding agent. This technique is also known as the total-etch technique.

In an effort to simplify dentine/enamel bonding systems, a SEP (fifth-generation dentine bonding system), which combines tooth surface etching and priming steps to simultaneously treat both enamel and dentine, was introduced (Miyazaki *et al.*, 1999). There was, however, some concern that the manufacturers were compromising enamel bond strength in their efforts to simplify clinical application (Miyazaki *et al.*, 1999). Research into the development of SEPs progressed even further with the introduction of single-application bonding systems that combined the SEP and the resin-bonding agent into a one-step formulation (Amra *et al.*, 2007); these are the sixth-generation bonding systems.

However, as chemically stable concentrations of the components (acid, primer, and adhesive) are difficult to achieve, the sixth-generation bonding systems are designed to store their components separately into two flasks until mixed for clinical use. Such component separation prevents changes in the initializers as they are sensitive to acidity over time (Van Meerbeek *et al.*, 2003).

In an effort to obtain a self-conditioning agent containing all its components mixed together in one flask only, seventh-generation SEPs have emerged. Among these, Xeno IV is one of the most widely used.

Xeno IV (Dentsply Caulk, Milford, Massachusetts, USA) is a self-etching adhesive system that is said to demonstrate high performance in terms of self-etching technology by providing a bond to enamel and dentine comparable with those of conventional adhesive systems with phosphoric acid conditioning (Nunes *et al.*, 2009). The unresolved question regarding Xeno IV is whether it is effective in orthodontic bonding.

The purpose of this study was to assess and compare the shear bond strength (SBS) of a one-step SEP system (Xeno IV) used to bond orthodontic brackets.

Materials and methods

One hundred and eighty extracted permanent bovine mandibular incisors were collected, cleaned of soft tissue, stored in 10 per cent formaldehyde solution, and kept in a refrigerator for 24 hours at 8°C. The criteria for tooth selection included intact buccal enamel, no previous chemical treatment (e.g. hydrogen peroxide), no cracks caused by extraction forceps, and no caries.

The teeth were inserted into PVC reducing bushes (Tigre, Joinville, Brazil) filled with acrylic resin (Clássico, São Paulo, Brazil) with only their crowns exposed. The buccal surfaces of the crowns were positioned perpendicular to the shearing base of the die using a glass square to enable correct mechanical testing. After polymerizing the resin, all samples were stored in distilled water and refrigerated for 24 hours at 8°C.

Prior to bonding, the buccal surfaces of all teeth were submitted to prophylaxis using rubber cups (Viking; KG Sorensen, Barueri, Brazil), extra-fine pumice stones (S.S. White, Juiz de Fora, Brazil), and water for 15 seconds. The samples were washed by applying an air/water jet for 15 seconds and dried with an air jet free of oil/humidity during the same period of time. The rubber cups were replaced after every five prophylactic procedures in order to maintain the experimental pattern.

After prophylaxis, the teeth were randomly divided into six groups ($n = 30$), and 0.018 inch stainless steel maxillary central incisor brackets with a base area of 14.2 mm^2 (Morelli, Sorocaba, Brazil) were used for bonding.

The six groups consisted of two control and four experimental groups (Table 1). Groups 1 and 5 were the control groups for Transbond XT (3M Unitek, Monrovia, California, USA) and Fuji Ortho LC (GC Corp., Tokyo, Japan) adhesives, respectively. Xeno IV was used in the other experimental groups (2, 3, and 6). In group 4 Fuji Ortho LC was used with no enamel conditioning procedure.

After prophylaxis, all samples from both control groups were etched with 37 per cent phosphoric acid for 20 seconds and then washed and dried for the same period of time.

Xeno IV was used according to the manufacturer's recommendations, that is application in two layers, photopolymerization for 15 seconds, and light application of an air jet. In group 4, the brackets were bonded on the cleaned dental surfaces but not etched.

Transbond XT and Fuji Ortho LC composites were applied on the bracket base and placed on the tooth with a force of 300*g* (Correx force gauge, Bern, Switzerland) for 10 seconds. The force was applied uniformly to ensure an even adhesive thickness between the bracket and enamel. Adhesive flash was removed from the teeth with a probe and each bracket was then light cured for 40 seconds (10 seconds on each side) at a distance of 1 mm from the bracket using a 2500 light-curing unit (3M Dental Products, Oakdale, California, USA) with a light intensity of 550 mW/cm^2. The light intensity was calibrated for each polymerization using a radiometer (Demetron, Danburry, Connecticut, USA).

The bonded teeth were left undisturbed for 30 minutes to ensure complete polymerization of the adhesive. After a 24 hour period of immersion in distilled water, all samples were subjected to thermocycling (500 cycles in 5°C and 55°C water with a dwell time of 15 seconds in each bath; Amra *et al.*, 2007).

In order to keep the sample stable during mechanical testing, a spiral-made device was used. SBS testing was performed using an Emic DL 10.000 universal testing machine (São José dos Pinhais, Paraná, Brazil) at a crosshead speed of 0.5 mm/minute through a chisel-shaped rod. The force per unit area required to dislodge the bracket was then calculated and reported as the SBS in megapascals (MPa).

The enamel surfaces were examined with a stereomicroscope (Stemi 2000-C; Carl Zeiss, Göttingen, Germany) at a magnification of ×16. The amount of composite

Table 1 Descriptions of the groups.

Control	Experimental
Group 1: 37% phosphoric acid/ Transbond XT primer + adhesive	Group 2: Xeno IV/Transbond XT primer + adhesive Group 3: Xeno IV/Transbond XT adhesive
Group 5: 37% phosphoric acid/ Fuji Ortho LC	Group 4: Fuji Ortho LC Group 6: Xeno IV/Fuji Ortho LC

remaining was classified according to the adhesive remnant index (ARI; Årtun and Bergland, 1984). The ARI scores range from 0 to 3, with 0 indicating no composite left on the enamel; 1, less than half of the composite left; 2, more than half of the composite left; and 3, all composite left on the tooth surface (Årtun and Bergland, 1984).

Statistical analyses were performed using the Statistical Package for Social Sciences version 13.0 (SPSS Inc., Chicago, Ilinois, USA). Descriptive statistics that included the mean, standard deviation, and median values were calculated for all six groups. Analysis of variance was used to determine whether significant differences existed among the groups. For the *post hoc* test, the Tukey's test was used. Kruskal–Wallis and Mann–Whitney U-tests were used for assessing the ARI scores.

Results

There were no statistical differences between groups 1, 2, and 3. However, statistically significant differences were found between groups 4, 5, and 6. Statistical differences were also observed when groups 4, 5, and 6 were compared with each other (Table 2).

The groups where Transbond XT was used had the highest mean value, whereas those bonded with Fuji Ortho LC with no enamel conditioning had the lowest mean value.

The results regarding ARI score showed no statistical differences between groups 1, 2, and 3, 5 and 6. Group 4 had different results compared with the other groups (Table 3).

Table 2 Shear bond strength comparisons.

Group	Mean (MPA)	SD	Median	Range	Significance*
1	21.88	1.09	22.02	20–23.19	A
2	21.83	1.54	21.61	18.62–24	A
3	20.74	1.064	20.81	19.27–22.8	A
4	6.12	1.21	6.4	3.09–7.54	B
5	17.76	1.84	18.16	14.09–20.73	C
6	15.81	1.17	15.45	14.15–18.63	D

*The same letters indicate absence of a statistically significant difference ($P > 0.05$).

Table 3 Frequency distribution of adhesive remnant index scores.

Group	Score				Significance*
	0	1	2	3	
1	8 (26.6%)	6 (20%)	14 (46.6%)	2 (6.66%)	A
2	8 (26.6%)	16 (53.3%)	2 (6.66%)	4 (13.3%)	A
3	12 (40%)	6 (20%)	10 (33.3%)	2 (6.66%)	A
4	28 (93.3%)	2 (6.66%)	0 (0%)	0 (0%)	B
5	4 (13.3%)	8 (26.6%)	14 (46.6%)	4 (13.3%)	C
6	2 (6.66%)	12 (40%)	14(46.6%)	2 (6.66%)	C

*The same letters indicate absence of a statistically significant difference ($P > 0.05$).

The highest mean ARI was observed in group 5 (1.6), where Fuji Ortho LC composite was used and the enamel was conditioned with 37 per cent phosphoric acid, and the lowest in group 4.

Discussion

Xeno IV is a self-conditioning adhesive requiring one application as the composite is stored in one flask only, thus needing no prior mixing. In the succeeding scale of adhesives, Xeno IV is considered a seventh-generation self-etching adhesive system.

The present research assessed the SBS of orthodontic brackets bonded with Xeno IV. Self-etching agents have been available in the dental market only recently. These materials are classified as self-etching agents because they characteristically etch the enamel while being applied.

The study sample comprised 30 teeth per group in order to minimize any strong divergence from the mean values. According to Fox *et al.* (1994), conclusions regarding *in vitro* bond strength tests should be considered valid for samples consisting of 20–30 specimens.

Orthodontic adhesives are routinely exposed to temperature variations in the oral cavity. Air temperature, humidity, and velocity of air breathing can also alter resting oral temperature (Gale and Darvell, 1999). Although these variations are erratic and hard to anticipate when testing, it is important to determine whether they introduce stresses in the adhesive that might influence its bond strength. Therefore, Bishara *et al.* (2003) suggested that thermal cycling should form part of the test protocol of new adhesives. Thus, in the present study, all samples were thermocycled for 500 cycles in water between 5°C and 55°C with a dwell time of 15 seconds in each bath—a method proposed by Amra *et al.* (2007) for evaluating a sixth-generation adhesive (Xeno III).

The results of the present study showed that the use of Xeno IV self-etching adhesive associated with Transbond XT composite does not reduce the SBS, thus demonstrating the viability of Xeno IV in bracket bonding. These results are corroborated by other studies comparing phosphoric acid conditioning in association with sixth-generation self-etching adhesives (Bishara *et al.*, 2008; Dorminey *et al.*, 2003; Hirani and Sherriff 2006; Faltermeier *et al.*, 2007; Turk *et al.*, 2007).

Nevertheless, statistical differences were found in the SBS of brackets bonded with the resin-modified glass ionomer cement (Fuji Ortho LC). The lowest mean value was observed in the group where Xeno IV was used without enamel conditioning. On the other hand, the highest mean value was obtained when using the technique recommended by the manufacturer, that is enamel conditioning with 37 per cent phosphoric acid.

Although the values achieved in group 6 (Fuji Ortho LC + Xeno IV) were found to be statistically different compared with the other groups, the bond strength was sufficient to resist masticatory forces. Reynolds (1975) stated that 6–8 MPa resistance is sufficient to withstand masticatory forces.

One of the goals of clinicians is to avoid any damage to the enamel surface following debonding. Adhesive failures at the adhesive–bracket interface or even within the adhesive compound are more desirable than at the enamel–adhesive interface, as the latter situation results in fractures and fissures during bracket debonding (Cal Neto and Miguel 2004).

The ARI (Årtun and Bergland 1984) is an excellent way to obtain information on the quality of adhesion between the composite and tooth as well as between the composite and bracket base. The results showed that groups 1, 2, 3, 5, and 6 had more fractures at the adhesive–bracket interface. In group 4, where no enamel conditioning was performed, ARI scores of 0 and 1 were more predominant, thus contraindicating such a procedure for clinical use due to the higher risk of fracture.

Conclusion

According to the results the present study, it can be concluded that:

1. Xeno IV self-etching adhesive can be used to bond orthodontic brackets in association with Transbond XT composite.
2. The use of Xeno IV and Fuji Ortho LC resin-modified glass ionomer cement results in decreased bond strength compared with traditional methods, although it is sufficient to withstand masticatory forces.
3. The use of Xeno IV optimizes the procedure of bonding orthodontic brackets.

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