European Journal of Orthodontics 30 (2008) 94–99
doi:10.1093/ejo/cjm089
Advance Access publication 7 November 2007

Eighteen-month bracket survival rate: conventional versus self-etch adhesive

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SUMMARY The aim of this study was to evaluate, over an 18-month period, the clinical performance of a self-etch adhesive [Transbond Plus Self Etching Primer (SEP), 3M Unitek] compared with a conventional adhesive that employs the etch-and-rinse approach (Transbond XT, 3M Unitek). One operator, using the straight-wire technique, bonded 567 metallic brackets to the teeth of 30 patients (age range 12–18 years) in a way that patients acted as self-control. The brackets were bonded following the manufacturers' instructions except for the fact that the self-etch system was brushed for a longer time than recommended (10–15 seconds) since previous investigations have reported that prolonged application times can improve the bonding efficacy of self-etch systems to enamel. The failure modes were visually classified into: adhesive-enamel, adhesive-bracket, and cohesive failure. The survival rates of the brackets were estimated by Kaplan–Meier and log-rank test ($P < 0.05$).

The failure rates of the self-etch and conventional adhesives were 15.6 and 17.6 per cent, respectively. No significant differences in the survival rate were observed between the materials ($P > 0.05$). Most of the failures were cohesive and at the adhesive–enamel interface. There was no difference in the fracture debonding mode. These findings indicate that Transbond Plus SEP can be safely used for orthodontic brackets since the survival rates are similar to the conventional Transbond XT.

Introduction

It is essential, in orthodontic practice, to achieve a reliable adhesive bond between an orthodontic attachment and tooth enamel. In order to reduce chair-time, a new group of adhesives were introduced in orthodontics and termed as 'self-etch adhesives' (Miller, 2001). These systems combine both the conditioner and primer in a single acidic primer solution, allowing the elimination of acid conditioning and rinsing, required for conventional bonding systems. Therefore, the self-etch primers (SEP) can simultaneously etch and infiltrate the enamel surface (Van Meerbeek *et al.*, 2003).

SEP have only recently been introduced in the orthodontics. One of these self-etch systems is the Transbond Plus SEP (3M Unitek, Monrovia, California, USA). This material contains methacrylated phosphoric acid-esters as the main ingredient and has a pH of approximately 1.0. The phosphate group of the methacrylated phosphoric acid-ester dissolves the calcium and removes it from the hydroxyapatite. Rather than being rinsed away, as phosphoric acid is, the calcium forms a complex with the phosphate group and is incorporated into the hybridized complex after light-curing. Research in the associated field of restorative dentistry has shown that the use of SEP produces a less-defined enamel-etching pattern compared with that resulting from the conventional acid-etching technique (Di Hipólito *et al.*, 2005; Moura *et al.*, 2006). However, no direct correlation between specific etching patterns and bond strengths has been identified.

The orthodontic literature lists a limited number of studies on the performance of SEP and the great majority of them are laboratory investigations. According to these studies, Transbond Plus provides shear bond strengths (SBS) similar to those achieved with etch-and-rinse adhesives (Arnold *et al.*, 2002; Buyukyilmaz *et al.*, 2003; Cacciafesta *et al.*, 2003; Dorminey *et al.*, 2003; Rajagopal *et al.*, 2004; Bishara *et al.*, 2005). However so far, only a few short-term clinical trials have attempted to compare the survival rates of brackets bonded with these different bonding strategies (Ireland *et al.*, 2003; Aljubouri *et al.*, 2004; Manning *et al.*, 2006; Santos *et al.*, 2006). Ireland *et al.* (2003) found that the conventional system, based on the etch-and-rinse approach, were superior to self-etch Transbond Plus after 6 months. This finding was not observed in other 6- and 12-month clinical evaluations (Aljubouri *et al.*, 2004; Pandis *et al.*, 2006; Santos *et al.*, 2006). Aljubouri *et al.* (2004) detected a slight but non-significant difference on the 12-month failure rate between a self-etch (1.6 per cent) and a conventional adhesive (3.1 per cent). Santos *et al.* (2006) showed that the failure rate of the conventional system was 0.43 times greater than that of the self-etch system. Manning *et al.* (2006) reported failure rates over the duration of the fixed appliance treatment of 7.4 per cent for a conventional adhesive and 7.0 per cent for the self-etch material.

The lack of long-term clinical trials and the apparent contradictory findings among the short-term clinical studies highlight the need for more clinical trials in order to reach a consensus on the performance of this new adhesive strategy. Therefore, it was the aim of this longitudinal randomized clinical study to compare, over an 18-month period, the clinical performance of a self-etch and a conventional system.

Materials and methods

Ethical approval for this study was obtained from the University of Passo Fundo Research Committee (Passo Fundo, Rio Grande do Sul, Brazil). A total of 90 patients (12–18 years) were recruited from the waiting list of the Orthodontic Dental Clinic at the University of Oeste de Santa Catarina, Joaçaba, Santa Catarina, Brazil. However, only 30 patients who met the inclusion criteria were selected. These patients did not have any restorations in the buccal surfaces of teeth where brackets were to be bonded and did not have any accentuated occlusal dysfunction that could affect bracket positioning. Patients with very poor oral hygiene were not included in this study. There was no restriction on the type of malocclusion.

Before the beginning of the orthodontic treatment, all patients were instructed in oral hygiene and dental care. If restorative or extraction procedures were needed, they were performed before the start of orthodontic treatment. The details of the sample size, mean age, and patient distribution by gender, age, and tooth type are shown in Table 1.

The minimum sample size was calculated considering the retention rate of Transbond XT at 18 months to be 90 per cent. Using an α of 0.05, a power of 90 per cent, and a one-sided test, the minimum sample size should be 263 brackets in each group in order to detect a difference of 10 per cent between groups.

A total of 567 brackets were bonded, according to the straightwire technique. A single operator (JES) performed the bonding procedures in order to eliminate interexaminer variation. The teeth were cleaned with pumice slurry using a rubber cup before the application of one of following two adhesives: (1) Transbond XT light cure orthodontic adhesive (3M Unitek) and (2) Transbond Plus SEP (3M Unitek). The modes of application of these materials were as follows:

Transbond XT light cure orthodontic adhesive: acid etching (15 seconds), rinsing (15 seconds), air dry (5 seconds), primer application (15–20 seconds), placement of the resin paste on the bracket, and light-curing with halogen light (450 mW/cm^2, XL 1500, 3M ESPE, St Paul, Minnesota, USA) for 60 seconds and

Transbond Plus SEP: mixture of the components, priming application under rubbing motion for 10–15 seconds, slight airstream (at a distance of 10 cm for 5 seconds), placement of the resin paste on the bracket, and light-curing with halogen light (450 mW/cm^2, XL 1500, 3M Espe) for 60 seconds.

The mode of application of the Transbond Plus SEP did not follow the manufacturers' directions. The adhesive was rubbed onto the enamel for 10–15 seconds instead of the recommended 3 seconds, since previous investigations have reported that prolonged application times can improve the bonding efficacy of self-etch systems to enamel (Ferrari *et al.*, 1997; Perdigão *et al.*, 2006).

The brackets were bonded so that homologous teeth from the same arch received different materials, i.e the patient acted as a self-control. Usually the split-mouth design is used but if the patients had occlusal problems on just one side of the mouth, the brackets bonded on that side would be more prone to failure. A coin was tossed to determine the order of the teeth in each quadrant to be bonded in each patient.

After adhesive application, stainless steel brackets Dyna-Lock Twin Roth.022 inch (3M Unitek #118-122) were coated with Transbond XT light cure paste (3M Unitek). The brackets were positioned in the centre of the crown (Roth, 1981) and pressure was applied to seat each bracket fully before removing any excess resin. The light-curing procedure was performed with a curing light XL 1500 (3M Espe) for 20 seconds at the mesial aspect, 20 seconds at the incisal–occlusal aspect, and 20 seconds more at the distal aspect. The light-curing intensity was checked regularly.

Every effort was made to minimize variation in the magnitude of orthodontic force applied to the brackets and

Table 1 Sample characteristics.

	Number	Per cent
Number of patients	30	—
Distribution of patients by gender		
Female	15	50
Male	15	50
Distribution of patients by age (years)		
12–13	8	26.7
14–15	10	33.3
16–18	12	40
Number of brackets	567	
Distribution of brackets by gender		
Female	283	49.9
Male	284	50.1
Distribution of brackets by age (years)		
12–13	150	26.5
14–15	188	33.1
16–18	229	40.4
Distribution of brackets by tooth type		
Upper incisors	120	21.1
Lower incisors	119	21
Upper canines	60	10.6
Lower canines	60	10.6
Upper premolar	100	17.6
Lower premolars	108	19.1
Distribution of brackets by bonding material		
Conventional	284	51.1
Self-etch	283	49.9

teeth. The usual choice of aligning archwires was either a 0.0012 inch NiTi or 0.014 inch NiTi wire depending on the initial level of alignment and crowding. In this study, a 0.014 inch archwire was ligated at least 10 minutes after the bonding procedure. No bite-planes appliances were used during the treatment.

The patients were seen at intervals of 40 days; however, they were instructed to check for loose or missing brackets daily. A data sheet was used for each patient to record the date of bracket failure and the teeth involved. Bracket failure was visually classified as at the adhesive–enamel interface if there was no material left on the tooth surface and as adhesive–bracket interface failure by the total absence of adhesive on the bracket base. Cohesive failure was classified according to the presence of some material on the tooth surface and the bracket base.

The brackets were replaced immediately after bond failure was detected: new bonded brackets were not included in the study. All patients were observed for 18 months during their regular orthodontic appointments. The bracket failures were summarized per month for statistical analysis.

The survival rates of the brackets were estimated by Kaplan–Meier test. The log-rank test, with the level of significance set at 0.05, was used to compare the survival curves. Descriptive statistics were used to describe the frequency distributions of the different failure modes for each adhesive system and they were evaluated by a Fisher's exact test ($\alpha = 0.05$).

Results

A total of 94 brackets (16.6 per cent) failed over the 18-month period. For the Transbond Plus SEP, 44 brackets failed (15.6 per cent) and for conventional system, 50 brackets failed (17.6 per cent). Figure 1 shows the influence of bonding material on survival rate. No significant difference was observed between materials ($P = 0.44$). The self-etch adhesive ($S[t] = 0.602$) showed a higher survival rate than the conventional system ($S[t] = 0.622$), although this difference was not statistically significant. The number of failed brackets, distributed according to material and failure mode, is shown in Table 2. Most failures occurred at the adhesive–enamel or at adhesive–bracket interface. No significant difference was observed for either material ($P = 0.22$).

Discussion

The failure rates observed in this study were high compared with other investigations (Pandis and Eliades, 2005). However, the present failure rates were within the range of other randomized clinical trials, ranging from 2.7 to 23 per cent (Lovius *et al.*, 1987; De Saeytijd *et al.*, 1994; Fowler, 1998; Sunna and Rock, 1998; Littlewood *et al.*, 2001).

These differences depend on the type of light-cured composite, the length of the observation period, and the trial design. Therefore, it is difficult to make direct comparisons of bracket failure rates between studies due to the variation in the number of operators, bonding techniques and materials, research designs, and trial duration. Pandis and Eliades (2005) reported that differences in failure rates and contradictory evidence from studies testing identical materials in different populations imply that culturally influenced dietary habits and gender differences can affect the failure rate of brackets *in vivo*. Thus, the variability observed among studies with regard to failure rates or jaw distribution and arch location could be assigned to the foregoing factors.

The preliminary 6-month report of the present study showed a significantly higher survival rate of the Transbond Plus SEP compared with the Transbond XT (Santos *et al.*, 2006). Another short-term clinical trial also reported that the overall failure rate of Transbond Plus at 6 months to be lower than the corresponding values for the etch-and-rinse adhesive. However, after long-term evaluation, no difference between the materials could be detected. The results of the present clinical trial compare well with those of another clinical investigation (Aljubouri *et al.*, 2004).

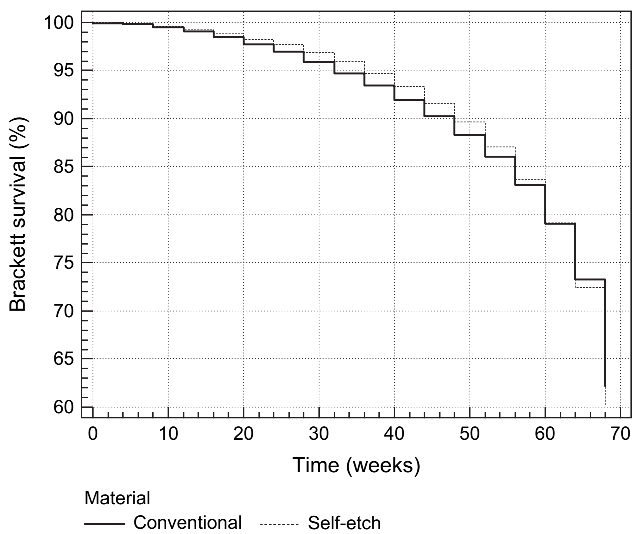

Figure 1 Relationship between bracket survival rate (per cent) and duration of treatment (weeks) for the materials used for bonding.

Table 2 Number of debonded brackets according to material and fracture pattern*.

Material	Enamel–resin	Bracket–resin	Cohesive	Total
Conventional	15	5	30	50
Self-etch	18	1	25	44

*No significant difference between materials ($P = 0.22$).

A recent study (Cal-Neto and Miguel, 2006) compared the etching pattern produced by conventional phosphoric acid and Transbond Plus SEP. Enamel etching with phosphoric acid creates an etching pattern characterized by a selective and uniform demineralization area, which are infiltrated by the resin of the adhesive in order to produce well-formed resin tags into demineralized surface. The phosphoric acid increases the superficial roughness rendering the enamel more receptive for bonding. With regard to the self-etch systems, Cal-Neto and Miguel (2006) reported an etching pattern similar to the conventional phosphoric acid treatment, except for the fact that the depth of etching was slightly lower than the phosphoric acid-treated enamel. In fact, this finding was also expected due to the lower acidity of Transbond Plus. Pashley and Tay (2001) reported that the etching pattern of strong self-etch systems, i.e., those with a pH value lower than 1, was similar to that of phosphoric acid treatment.

The similar etching pattern between conventional and self-etch adhesive explains why most laboratory evaluations showed a superior or similar performance for Transbond Plus SEP compared with conventional Transbond XT on dry enamel (Arnold *et al.*, 2002; Buyukyilmaz *et al.*, 2003; Dorminey *et al.*, 2003; Bishara *et al.*, 2005). As bracket bonding is not usually performed under rubber dam isolation, a completely dry field is not easily accomplished. This means that any possible contamination can compromise the retention of the appliances, mainly when a moisture-sensitive material is employed. Contrary to the hydrophobic features of conventional Transbond XT, the self-etch adhesive is hydrophilic and therefore this material can achieve high bond strength values even when the enamel is contaminated with saliva or water (Cacciafesta *et al.*, 2003; Zeppieri *et al.*, 2003; Campoy *et al.*, 2005). The presence of hydrophilic monomers and solvents in the Transbond Plus SEP composition means that this material is less moisture sensitive (Santos *et al.*, 2006), since the solvents are capable of displacing water from the surface, which facilitates the adhesive penetration into enamel microporosities (Jain and Stewart, 2000). This also explains the improved initial performance of this system compared with conventional etch-and-rinse adhesive.

On the other hand, the hydrophilic feature of these monomers increases the water sorption of this material, which may render the adhesive interface weaker and lead to bracket debonding (Littlewood *et al.*, 2001). This could be one of the reasons why the self-etch adhesive was superior at 6 months and similar to the conventional system at 18 months.

Ireland *et al.* (2003) reported an inferior performance of Transbond Plus compared with the Transbond XT after 6 months. Aljubouri *et al.* (2004) showed similar results after 6 and 12 months. It is likely that the differences in the mode of application of the self-etch system between the present study and those of Aljubouri *et al.* (2004) and Ireland *et al.* (2003) could have played a role in the findings. Aljubouri *et al.* (2004) and Ireland *et al.* (2003) applied the self-etch adhesive following the manufacturer's instructions, i.e., brushing it for only 3 seconds on the enamel surface before the application of an airstream and light-curing. Previous reports on self-etch systems have demonstrated that rubbing the self-etch adhesives on the enamel surface (Miyazaki *et al.*, 2002) or applying it for double the recommended time (Ferrari *et al.* 1997; Perdigão *et al.* 2006) can increase the resin–enamel bond strength and improve the sealing and etching pattern of enamel.

Bearing in mind the findings of these previous *in vitro* investigations, the Transbond Plus was applied for 10–15 seconds in this study. This means an increase of three-to-five times the manufacturer's recommended application time. This could be the reason for the differences observed in the present study and that of Ireland *et al.* (2003). However, as the current investigation did not aim to evaluate the effect of the priming time of the Transbond Plus on survival rate, this hypothesis should be evaluated in future clinical and laboratory studies.

It is claimed that one of the main advantages of Transbond Plus is that this system results in a shorter chair-side time. Aljubouri *et al.* (2004) reported that the mean difference in bracket-bonding time per patient between the two bonding systems was almost 25 seconds; i.e. on average, each bracket bonded using the self-etch adhesive took 25 seconds less than Transbond XT. Although this study did not aim to measure the bracket-bonding time of both systems, it is likely that more time was used for Transbond Plus SEP since application did not follow the manufacturers' instructions. However, it seems that even after rubbing the adhesive for a prolonged time, this material still results in a reduction of clinical chair-side time for both clinicians and patients and offers, therefore, increased patient comfort (Bishara *et al.*, 2005). Apart from that, both groups (self-etch and conventional) were pumiced and it is well established that pumicing prior to conventional etching is not required (Ireland and Sherriff, 2002). Therefore, if pumicing is not performed prior to conventional etching and the application time of Transbond Plus SEP is prolonged, it is likely that these materials will require similar chair-time for application.

An ideal orthodontic adhesive should have adequate SBS while maintaining unblemished enamel (Diedrich, 1981). Adhesive remnant index determination shows the cohesive or adhesive nature of the orthodontic bond. Adhesive failures, at the enamel surface, might be the result of a reduced depth of demineralization; therefore, less adhesive remains on the tooth, thus decreasing the time required to clean the enamel surface (Hosein *et al.*, 2004). Usually, the use of conventional bonding techniques shows mainly cohesive bond failure (Rix *et al.*, 2001; Hosein *et al.*, 2004; Trites *et al.*, 2004). Velo *et al.* (2002) and Bishara *et al.*

(1999) studied self-etch adhesive bond failures and found adhesive failure rather than cohesive detachment at debond.

Contrary to these aforementioned findings, this study showed no differences in the frequency of failure modes observed between the materials. According to Diedrich (1981), the failure mode of brackets depends, among other factors (cohesive strength of the adhesive, bracket base morphology, etc.), on the resin–enamel bond strength values achieved by the bonding systems. Bonding materials with a low bond strength to enamel tend to debond at the adhesive/enamel interface, whereas materials with high enamel–resin bond strength tend to show cohesive failures or adhesive/bracket debonding. As previously mentioned, these two systems (Transbond XT and Transbond Plus) behave similarly with regard to bond strength evaluations and therefore this finding can explain the similar results concerning the failure modes (Arnold *et al.*, 2002; Buyukyilmaz *et al.*, 2003; Cacciafesta *et al.*, 2003; Dorminey *et al.*, 2003; Rajagopal *et al.*, 2004; Bishara *et al.*, 2005).

Conclusions

Transbond Plus can be safely used for orthodontic bracket bonding since its performance is equal to conventional Transbond XT.

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Funding

CNPq grants (473101/2006-8) and (305870/2004-1).

Acknowledgements

The authors of this study are grateful to 3M Unitek for providing the Transbond Plus SEP used in this clinical study.

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