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Microleakage between composite–wire and composite–enamel interfaces of flexible spiral wire retainers. Part 1: comparison of three composites

Tancan Uysal*, Asli Baysal*, Serdar Usumez** and Mustafa Ulker***
Departments of *Orthodontics and ***Conservative Dentistry, University of Erciyes, **Department of Orthodontics, University of Gaziantep Turkey

SUMMARY The aim of this investigation was to test the hypothesis that there is no difference in microleakage between composite–enamel and composite–wire interfaces, when different composites are used. Forty-five freshly extracted human mandibular incisors separated into three groups were used in the study. Multi-stranded 0.0215 inch diameter wire was bonded to enamel using two conventional (Transbond XT and Transbond LR) and a flowable (Venus Flow) orthodontic composite. The specimens were sealed with nail varnish, stained with 0.5 per cent basic fuchsine for 24 hours, sectioned and examined under a stereomicroscope, and scored for microleakage at the composite–enamel and composite–wire interfaces from the mesial and distal margins. Statistical analysis was performed using Kruskal–Wallis and Mann–Whitney *U*-tests with a Bonferroni correction.

Little or no microleakage was observed between the composite–enamel interfaces for the three investigated composites, and any difference was not statistically significant. However, statistically significant differences were found between microleakage at the composite–wire interface for both the conventional and flowable composite groups ($P < 0.001$). Flowable composite showed the highest leakage (mean: 4.8 ± 0.8 mm), while Transbond XT (mean: 0.5 ± 0.3 mm) and Transbond LR (mean: 1.1 ± 1.2 mm) showed significantly lower and comparable results. The amount of microleakage at the wire–composite interface was significantly greater than that at the enamel–composite interface of flexible spiral wire retainers (FSWRs). The null hypothesis is therefore rejected. Flowable composites may not be appropriate for bonding FSWRs.

Introduction

Bonded lingual retainers are the appliance of choice in the mandibular incisor area since the relapse potential is unpredictable and a continuous decrease in the mandibular arch results in anterior crowding, even in non-growing patients. Bonded lingual retainers are fabricated in various designs which consist of a combination of different wires in various sizes and of different compositions (Årtun *et al.*, 1987). It appears that flexible spiral wire retainers (FSWRs) have replaced plain round wires because their flexibility allow physiologic movement of teeth and they provide mechanical retention to the composite, thus avoiding retentive bends (Zachrisson, 1985, 1986; Bearn, 1995).

Different composites have been described for use with this technique including both restorative and orthodontic bonding materials. Several manufacturers have developed adhesives for lingual retainer bonding and claimed that these adhesives offer ease of application and optimal handling characteristics. These highly filled, light-cured resins are also said to be a better choice when longevity and durability are required (Usumez *et al.*, 2003, 2005). However, time-consuming trimming and finishing are often necessary to obtain optimal results (Elaut *et al.*, 2002). Flowable composites, which were originally created for use in restorative dentistry by increasing the resin content of traditional microfilled composites, have been suggested for bonding lingual retainers (Elaut *et al.*, 2002; Geserick and Wichelhaus, 2004; Geserick *et al.*, 2004). These composites are claimed to be advantageous in restorative dentistry as no mixing is required, needle tips on the application syringes allow direct and precise composite placement, the composite is not 'sticky', and since the material flows towards the bulk of the material rather than away from it, no trimming and polishing are required and chair time is reduced (Elaut *et al.*, 2002).

When failure rates are compared, larger round stainless steel wires are superior to thinner stranded wires (Zachrisson, 1977, 1995; Årtun *et al.*, 1997). The most common failure type is detachment at the composite–wire interface because of insufficient adhesive over the wire or unfavourable occlusal contacts which results in abrasion of the composite (Zachrisson, 1977; Årtun and Urbye, 1988; Dahl and Zachrisson, 1991). The second most common reason for failure is detachment at the composite–enamel interface.

Microleakage beneath bonded orthodontic attachments may be a reason for these types of failures. In the orthodontic literature, different band cements (Gillgrass *et al.*, 1999), light sources (James *et al.*, 2003), and brackets (Arikan *et al.*, 2006, Ramoglu *et al.*, 2009, Ulker *et al.*, 2009; Uysal *et al.*, 2008b) have been evaluated for microleakage but these studies primarily focused on enamel demineralization. FSWRs are intended to serve for a long time in the mouth and are subject to various chemical and mechanical degradation (Ramoglu *et al.*, 2008). However, there is no *in vivo* or *in vitro* information concerning the effect of composite type on microleakage of FSWR. It is also not clear whether flowable composites will resist microleakage as well or better than regular orthodontic resins.

To date, no studies have been published in the literature comparing the microleakage of lingual retainer composites when used for FSWR purposes. Therefore, the aim of this study was to evaluate microleakage between composite–enamel and composite–wire interfaces when different composites are used. For the purposes of this investigation, the null hypothesis assumed that different types of composites used for FSWR would not influence the amount of microleakage observed between composite–enamel and composite–wire interfaces.

Materials and methods

Approval for the study was granted by Erciyes University local ethics committee. To take account of ethical concerns, both small and large samples were included in this investigation.

Sample preparation

Forty-five non-carious human mandibular incisor teeth, extracted for periodontal reasons, were used in this study. The teeth were stored in distilled water. Immediately before bonding, the teeth were cleaned with a scaler and pumice in order to remove soft tissue remnants, calculus, and plaque. The teeth were separated into three equal groups. All samples were etched for 30 seconds with 37 per cent orthophosphoric acid (3M Dental Products, St Paul, Minnesota, USA), rinsed with water from a three-in-one syringe for 30 seconds, and dried with an oil-free source for 20 seconds.

Multi-stranded PentaOne® wire (Masel Orthodontics, Bristol, Pennsylvania, USA) 0.0215 inches in diameter was used in all groups. The wires were cut into 20 mm lengths in order to ensure standardization and bent to fit the lingual curvature of the incisor teeth.

The groups and sample preparation techniques were as follows (Figure 1).

Group I: A conventional orthodontic bonding composite, Transbond XT (3M Unitek, Monrovia, California, USA), was used. Before composite placement, Transbond XT primer (3M Unitek) was applied to the etched surface as a thin uniform coat. As recommended by the manufacturer, the primer was not cured. Transbond XT adhesive paste was then applied and cured for 20 seconds.

Group II: Transbond XT primer was applied as described for group I. Transbond LR (3M Unitek) was applied with an adhesive dispensing gun and cured for 20 seconds.

Group III: A flowable composite Venus Flow (Heraeus Kulzer, Dormagen, Germany) was applied following wire placement and primer application (Single Bond, 3M Espe Dental Products). The primer was cured for 10 seconds and the composite for 20 seconds.

The composite pastes were cured with a light-emitting diode (Elipar Free Light 2, 3M Espe Dental Products) for 20 seconds. Detailed descriptions of the composites used in this study are shown in Table 1.

To ensure stability during placement and contouring of the composite, the teeth were placed over a silicone putty compound (Zetaplus, Zhermack, Italy; Figure 2) and care was taken in inspecting the bonding area. The ends of the wires were secured with silicone putty to provide the best fit with the tooth surface (Uysal *et al.*, 2008a). During sample preparation, for standardization of the groups, care was taken to ensure that the bulk of the composite was 4 mm in diameter, with a composite thickness over the wire of 1 mm (Bearn *et al.*, 1997).

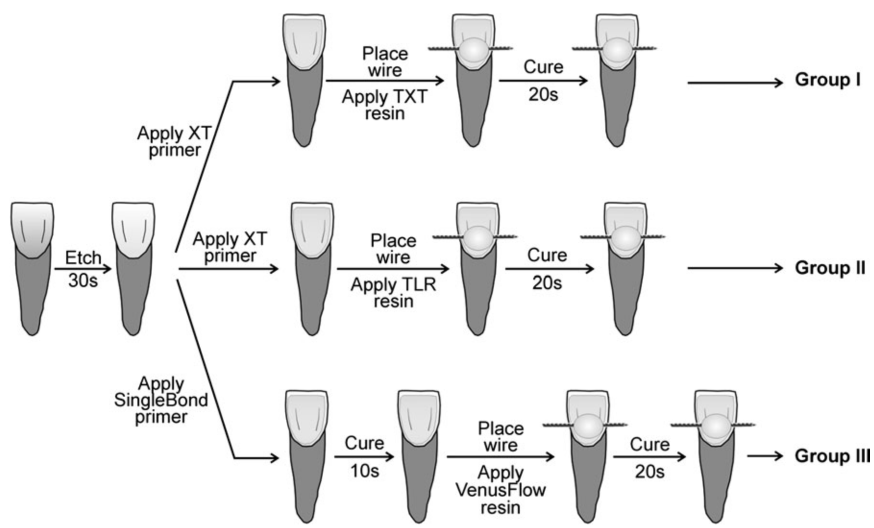

Figure 1 Flowchart for the application procedures.

Table 1 Composites and chemical compositions.

Material	Company	Component	Chemical composition	% by weight
Transbond XT™ light cure orthodontic adhesive	3M Unitek	Paste	Silane-treated quartz	70–80
			Bisphenol A diglycidyl ether dimethacrylate	10–20
			Bisphenol A bis(2-hydroxyethyl ether)dimethacrylate	5–10
			Silane-treated silica	<2
Transbond™ LR adhesive for lingual retainers	3M Unitek	Paste	Silane-treated quartz	75–85
			Bisphenol A diglycidyl ether dimethacrylate	5–15
			Triethylene glycol dimethacrylate	5–15
			Dichlorodimethylsilane reaction product with silica	<2
Venus Flow flowable composite	Heraeus Kulzer	Paste	Bis-Gma and Tegdma	60

Figure 2 The teeth were placed over silicone putty compound to ensure stability during placement and contouring of the composite.

Microleakage evaluation

Prior to dye penetration, the teeth apices were sealed with sticky wax. The teeth were then rinsed in tap water, air-dried, and nail varnish was applied to the entire surface of the tooth except for an area approximately 1 mm away from the composite bulk. To minimize dehydration of the specimens, the teeth were replaced in water as soon as the nail polish had dried. The teeth were immersed in a 0.5 per cent solution of basic fuchsine for 24 hours at room temperature. After removal from the solution, the teeth were rinsed in tap water, the superficial dye was removed with a brush, and the teeth were dried. Each composite bulk was sectioned in the transverse plane (parallel to the lingual retainer wire) just above the wire (Figure 3A) with a low-speed water-cooled diamond saw. The specimens were first evaluated under a stereomicroscope (×20 magnification; SZ 40, Olympus, Tokyo, Japan) for dye penetration along the composite–enamel interface at both the mesial and distal borders. The lingual retainer wires were then carefully removed from the composite bulk and the dye penetration between the composite–wire, both mesially and distally, was evaluated under a stereomicroscope (Figure 3B). Microleakage was determined by direct measurement using an electronic digital calliper (Mitutoyo Corporation, Miyazaki, Japan) and recording the data to the nearest value as a range of 0.5–5 mm.

Statistical analysis

For each composite interface (composite–enamel or composite–wire), the microleakage score was obtained by calculating the mesial and distal microleakage scores. Statistical analysis was performed using Kruskal–Wallis and Mann–Whitney *U*-tests with a Bonferroni correction (Statistical Package for Social Sciences, Version 10.0, SPSS Inc., Chicago, Illinois, USA). Intra- and interexaminer method error was evaluated by Kappa test. The level of statistical significance was set at $P<0.05$.

Results

Comparisons of mesial and distal microleakage scores for all specimens showed no statistically significant side differences ($P>0.05$). Thus, mesial and distal microleakage scores for each specimen were pooled and the microleakage scores for each composite and interface was determined by calculating the mean of the mesial and distal microleakage scores.

Specimens demonstrating mircoleakage (Figure 4) between the composite–enamel and descriptive statistics and comparisons of microleakage between the composite–enamel interfaces of the three composites are shown in Table 2. Little or no microleakage was observed for any group and the differences were not statistically significant ($P>0.05$). Therefore, the null hypothesis concerning the composite–enamel interface was not confirmed.

Descriptive statistics and the results of statistical testing for microleakage between the composite–wire interface are shown in Table 3. Kruskal–Wallis analysis of variance showed statistically significant differences among the investigated groups between the composite–wire interface ($P<0.001$). Therefore, the null hypothesis for the composite–wire interface was rejected. According to multiple comparisons, statistically significant differences were found between groups I and III and groups II and III ($P<0.001$). However,

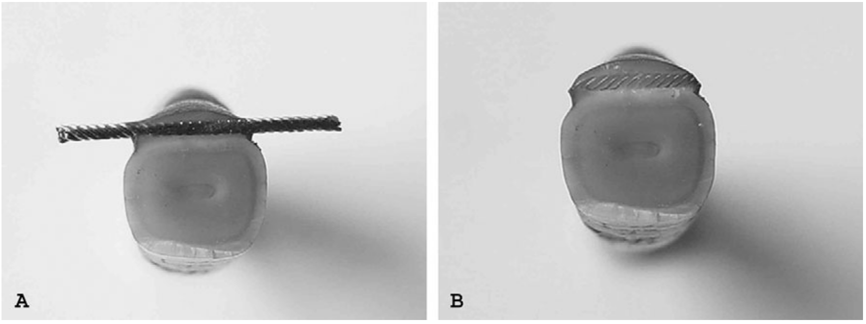

Figure 3 Transverse section showing the dye penetration along the enamel–composite (A) and wire–composite (B) interfaces.

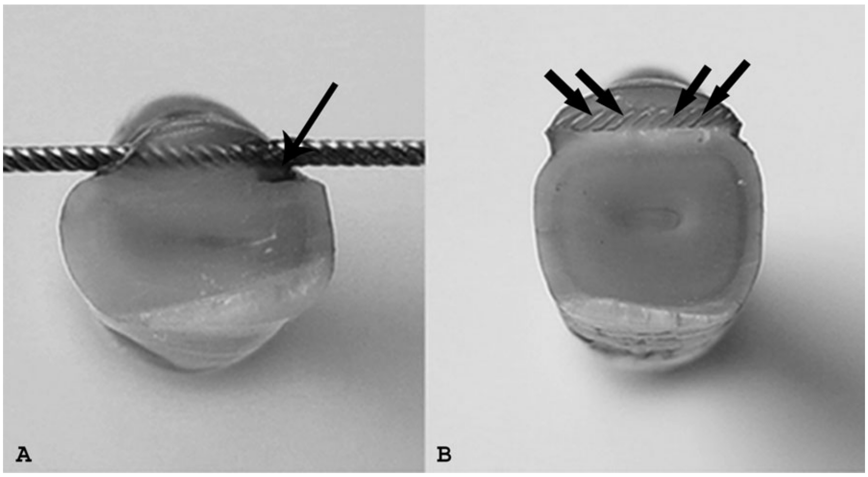

Figure 4 Specimens demonstrating microleakage between the composite–enamel (A) and composite–wire (B) interfaces.

Table 2 Microleakage between composite–enamel interface (mm).

Groups	*n*	*X*	SD	Range	Significance
Transbond XT	15	0.1	0.2	0.0–0.5	NS
Transbond LR	15	0.1	0.2	0.0–0.5	NS
Venus Flow	15	0.1	0.2	0.0–0.5	NS

NS, not significant.

no statistically significant difference was detected between groups I and II. Flowable composite showed the highest microleakage scores (mean: 4.8 ± 0.8 mm), while Transbond XT (mean: 0.5 ± 0.3 mm) and Transbond LR (mean: 1.1 ± 1.2 mm) showed significantly lower and comparable results.

Discussion

Abrasive wear of composite overlying the wire both in maxillary and mandibular FSWRs and placement of insufficient composite and detachment at the composite–wire interface are the main reasons for failure of lingual retainers (Bearn, 1995). On the other hand, microleakage, which is thought to be a major cause of white spot lesions (Gillgrass *et al.*, 1999; James *et al.*, 2003; Arikan *et al.*, 2006), may be another cause for failed retainers through detachment at the composite–wire and/or composite–enamel interfaces. This phenomenon is often ignored in orthodontics, but is an important cause of failures in restorative dentistry due to seepage and leaking of bacteria, fluids, or ions between the restorative material and dentine/enamel. This process may also cause secondary caries, post-operative pain, pulpitis, and sensitivity.

The type of resin material used may be important in terms of resistance to microleakage. Flowable resin composites are made using a variety of formulae and viscosities for different uses (Bayne *et al.*, 1998; Behle, 1998; Labela *et al.*, 1999; Moon *et al.*, 2002; Attar *et al.*, 2003; Bonilla *et al.*, 2003). These flowable composites are today extensively used in bonding orthodontic retainers (Elaut *et al.*, 2002, Geserick and Wichelhaus, 2004; Geserick *et al.*, 2004; Radlanski and Zain, 2004). However, it has been demonstrated that flowable composites may not be a good choice for bracket bonding (Uysal *et al.*, 2004), despite the fact that they show comparable shear bond strength and wire pull-out resistance values to regular orthodontic adhesives (Tabrizi *et al.*, 2009). However, the presence and amount of microleakage around FSWRs when different composites are used still remains unresolved.

Table 3 Microleakage between composite–wire interface (mm).

Groups	n	X	SD	Range	Significance	Multiple comparison	
						Group I	Group II
I. Transbond XT	15	0.5	0.3	0.0–1.0			NS
II. Transbond LR	15	1.1	1.2	0.5–5.0	***	NS	
III. Venus Flow	15	4.8	0.8	2.0–5.0		***	***

NS, not significant; $^{***}P<0.001$.

In the present study, the flowable resin of choice was Venus Flow as it has similar filler content (60 per cent) to Tetric Flow which was previously suggested by Radlanski and Zain (2004) and offers fluoride release and superior wear resistance. The other test materials were Transbond XT, which is a widely used orthodontic bonding material, and Transbond LR, which is an orthodontic composite produced for lingual retainer fabrication with claims of better handling properties.

The wire of choice for this testing procedure was 0.0215 inch PentaOne. This wire is commonly used in orthodontics for lingual retainer fabrication (Dahl and Zachrisson, 1991) and a study by Bearn *et al.* (1997) showed that an increased diameter from 0.0175 to 0.0215 inches significantly increased the force required to pull the wire from the composite.

In this study, cracked or fractured teeth were excluded, and due to limited availability of human teeth, teeth of different sizes were included. Thus, the bonding area was not standardized and curvature of the composite was determined according to individual tooth morphology. On the other hand, the preparation of all specimens was carried out by the same operator with attention to the shape of the bulk of composite (4 mm in diameter) and to ensure 1 mm of composite thickness over the wire (Bearn, 1995) which represents optimum properties for maximum strength and minimum expansion of the composite (Bearn *et al.*, 1997).

The dye penetration technique used in this study is easy to apply, fast, economical, and the most commonly employed method for determining microleakage of adhesive restorations (Taylor and Lynch, 1992). However, there are limitations which include the subjectivity of reading the specimens (Alani and Toh, 1997). To evaluate the measurement error in the present study, all specimens were scored by two operators at two different time intervals. Inter- and intraexaminer Kappa scores for assessment of microleakage were high with all values greater than 0.8.

According to Santini *et al.* (2004), bonding to enamel is stronger and more stable than bonding to dentine, and leakage along the enamel–composite interface is reduced or completely prevented. The literature also suggests that resistance of flowable composites to microleakage was similar to that of hybrid resin composites (Chimello *et al.*, 2002; Celiberti and Lussi, 2005). The results of this study confirm these results with no or little microleakage at the composite–enamel interface in any test group. Therefore, microleakage at the enamel seems not to be a concern with any of the composites when the longevity and clinical service life of FSWRs are considered.

However, the results for the composite–wire interface demonstrated the presence of significant leakage. The amount of microleakage at the wire interface was higher than at the enamel interface. It is clear that the presence of resin tags at the enamel surface by acid etching is an important factor (Celiberti and Lussi, 2005). Physiological tooth movement of the flexural retainer wire where it enters the resin core may also be an important factor which facilitates leakage at the wire–composite interface. This accounts for the fact that failure is most commonly observed at the wire–composite interface (Bearn, 1995). Microleakage between the wire and composite can contribute to detachment at this interface and can be a major source of failure. The leakage pattern at this interface showed statistically significant differences among the test groups. The amount of leakage was significantly higher with the flowable composite, Venus Flow (group III), while orthodontic composites Transbond XT and Transbond LR (groups I and II) showed comparable and significantly lower leakage scores. This may be due to lower filler load (by weight) or smaller particle size (0.7 μm) of the flowable composite.

The results of this study suggest that FSWRs present significantly higher microleakage at the composite–wire interface. The findings thus make the use of flowable composites for bonding FSWRs questionable. There is no doubt that flowable composites offer some clinical benefits (Elaut *et al.*, 2002), but they may not be appropriate for bonding FSWRs. However, caution should be exercised when applying the results of this laboratory study *in vivo* as the present findings may have shortcomings. The teeth and the retainer wires were examined immediately after bonding, while fixed lingual retainers are normally subject to ageing in the oral environment over time. It is still not clear to what extent leakage at the composite–wire interface contributes to the overall failure rate of FSWRs and whether all other flowable composite brands will yield the same leakage resistance values. With rapid advances in adhesive systems, newly developed products may overcome the shortcomings of flowable composites.

Conclusions

1. The amount of microleakage at the wire–composite interface was higher than that at the enamel–composite interface. No or little microleakage was observed at the composite–enamel interface, for all tested composites.
2. The flowable composite showed significantly higher leakage at the composite–wire interface when compared with conventional orthodontic composites.

Reference

The full list of references and address for correspondence is available in Part 2 (doi:10.1093/ ejo/cjp039).