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Microleakage between composite–wire and composite–enamel interfaces of flexible spiral wire retainers. Part 2: comparison of amorphous calcium phosphate-containing adhesive with conventional lingual retainer composite

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SUMMARY The aim of this study was to test the hypothesis that there is no difference in the microleakage values of a newly developed amorphous calcium phosphate (ACP)-containing adhesive and a conventional lingual retainer composite at the composite–enamel and composite–wire interfaces of flexible spiral wire retainers (FSWRs). Sixty freshly extracted human mandibular incisors separated into three equal groups were used in this study. Multi-stranded 0.0215 inch diameter wire was bonded to enamel using conventional orthodontic adhesive (Transbond LR, 3M Unitek) and ACP-containing composite (Aegis Ortho, Harry J. Bosworth Co.), with or without the use of a primer. 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 analyses were performed with Kruskal–Wallis and Mann–Whitney *U*-tests with a Bonferroni correction.

Little or no microleakage was observed between the composite–enamel interface for any of the three groups, and any difference was not statistically significant. The amount of microleakage at the wire–composite interface was higher than that at the enamel–composite interface. Multiple comparison testing showed statistically significant differences in microleakage between Transbond LR and the ACP-containing adhesive used with primer at the composite–enamel and composite–wire interfaces ($P < 0.001$). ACP-containing adhesive used with primer showed the highest microleakage scores at the composite–enamel (mean: 0.39 ± 0.42 mm) and composite–wire (mean: 1.66 ± 0.47 mm) interfaces. The hypothesis is rejected. The ACP-containing composite used with or without primer showed significantly higher leakage at the composite–wire interface, while conventional lingual retainer composite showed lower microleakage scores.

Introduction

There is general agreement on the necessity of fixed lingual retainers to prevent relapse after active orthodontic treatment (Bearn, 1995). With the evolution of acid etching in orthodontic practice, bonding provided new retention alternatives (Karaman *et al.*, 2003). Lingual retainers were made from smooth round or rectangular wires, but Zachrisson (1995) reported on the structural advantages of multi-stranded flexible spiral wire retainers (FSWRs) and indicated that because of their flexibility, these wires did not restrict physiological tooth movement. Thus, the multi-stranded structure provides extra mechanical retention with the bonding adhesive.

Polymerization shrinkage of adhesive materials may result in gaps between the adhesive material and enamel surface (James *et al.*, 2003). These gaps may cause seepage and leaking of fluids and bacteria between the tooth and adhesive surface, i.e. microleakage, thus facilitating the formation of white spot lesions on the enamel surface area (Gladwin and Bagby, 2004).

The demineralization pattern under composite is particularly important in orthodontics especially for lingual retainer adhesives as they are exposed to the oral cavity and are intended to remain in the mouth for a long period of time. Årtun (1984) investigated the potential caries and periodontal reactions associated with long-term use of different types of bonded lingual retainers and concluded that regardless of the type of wire involved in the construction of the 3–3 retainers, there is a tendency for plaque to accumulate along the retainer wires, and this tendency seems to increase with time.

In a recent study, Schumacher *et al.* (2007) developed a biologically active restorative material that may stimulate the repair of the tooth structure through the release of cavity fighting components including calcium and phosphate. This material contains amorphous calcium phosphate (ACP) as a bioactive filler encapsulated in a polymer binder (Skrtic *et al.*, 1996, 2004a; Antonucci and Skrtic, 2005).

ACP has the properties of both a preventive and restorative material that justify its use in dental cements, sealants, composites, and more recently, in orthodontic adhesives.

ACP-filled composite resins have been shown to recover 71 per cent of the lost mineral content of decalcified teeth (Skrtic *et al.*, 1996). One ACP-containing adhesive, Aegis Ortho, has been marketed for use as a light-cured orthodontic adhesive with similar properties to previously used resins. These materials promote the formation of hydroxyapatite, which in turn can lead to remineralization of enamel (Skrtic *et al.*, 2004b).

Recent studies have demonstrated the remineralization potential (Skrtic *et al.*, 1996, 2004a) or bracket bond strengths of ACP-containing materials (Dunn, 2007; Foster *et al.*, 2008); however, there are no studies in the literature that have investigated microleakage under FSWRs, when bonded with an ACP-containing orthodontic adhesive system. Therefore, the aim of this study was to determine and compare the microleakage at the composite–enamel and composite–wire interfaces of a conventional resin-based lingual retainer adhesive (Transbond LR) with a recently developed ACP-containing orthodontic adhesive system (Aegis Ortho).

For the purposes of this study, the null hypothesis assumed that there were no statistically significant differences between the microleakage of FSWRs bonded to enamel with the newly developed ACP-containing orthodontic composite and a conventional lingual retainer adhesive system.

Materials and methods

Sample preparation

Sixty fresh non-carious human mandibular incisor teeth extracted due to periodontal indications were used in this study. The incisors were preferred to simulate lingual retainer bonding. Teeth with hypoplastic areas, cracks, or gross irregularities of the enamel structure were excluded. The criteria for tooth selection dictated no pre-treatment with chemical agents such as alcohol, formalin, hydrogen peroxide, or any other form of bleaching. The teeth were stored in distilled water following extraction. The water was changed weekly to avoid bacterial growth. To obtain a favourable enamel surface for bonding, the teeth were cleaned with a scaler, pumice, and rubber cups in order to remove soft tissue remnants, calculus, and plaque. The teeth were separated into three equal groups.

Multi-stranded PentaOne® wire (Masel Orthodontics, Bristol, Pennsylvania, USA) with a diameter of 0.0215 inches was used in all groups. The wire was cut into 10 mm lengths in order to ensure standardization, and with a bend to fit the lingual curvature of the incisor teeth.

All samples were etched for 15 seconds with 37 per cent orthophosphoric acid (3M Dental Products, St Paul, Minnesota, USA), rinsed with water from a three-in-one syringe for 15 seconds, and dried with an oil-free source for 15 seconds. The groups and sample preparation techniques were as follows:

Group 1 (Transbond LR control): Before composite placement, Transbond XT primer (3M Unitek, Monrovia, California, USA) was applied to the etched surface as a thin uniform coat. The primer was cured for 10 seconds and, with an adhesive dispensing gun, a conventional orthodontic lingual retainer composite, Transbond LR (3M Unitek), was placed and cured.

Group 2 (ACP-containing adhesive with primer): Aqua Bond® Light-Cure Universal Bond (Harry J. Bosworth Co., Skokie, Illinois, USA) was applied to the etched surface and cured as Group 1. ACP-containing orthodontic adhesive Aegis Ortho (Harry J. Bosworth Co.) was then added and cured.

Group 3 (ACP-containing adhesive without primer): Aegis Ortho, ACP-containing orthodontic adhesive paste was applied to the etched surface and on the retainer wire using hand instruments and a brush and cured.

A quartz tungsten halogen light unit (Hilux 350, Express Dental Products, Toronto, Canada) was used for curing the specimens for 40 seconds. Curing was performed from the mesial, distal, gingival, and incisal margins of the composite bulk with the tip of the light unit placed as close as possible. The specimens were then stored in distilled water at 37°C for 24 hours before microleakage evaluation.

Microleakage evaluation was undertaken as described in Part 1.

Statistical analysis

For each composite interface (composite–enamel or composite–wire), the microleakage score was obtained by calculating the mesial and distal microleakage scores. After statistical evaluation of each specimen, the score for each composite and interface was obtained by calculating the mean of the mesial and distal microleakage scores.

Statistical evaluation of microleakage values between the test groups was performed using Kruskal–Wallis and Mann–Whitney *U*-tests with Bonferroni correction. Intra- and interexaminer method error was evaluated by kappa test. The level of significance was set at $P < 0.05$.

Results

Two examiners (MU and HE) assessed microleakage scores. Twenty specimens were randomly selected 1 week later and re-examined. Intra- and interexaminer kappa scores for assessment of microleakage were high, with all values greater than 0.85.

Descriptive statistics and comparisons of mesial and distal microleakage scores for the three groups between composite–enamel and composite–wire interfaces are shown in Table 1. Little or no microleakage was observed for the mesial and distal sides in any groups (mean range: 0.03–1.70 mm), and the differences were not statistically significant ($P > 0.05$). Thus, mesial and distal microleakage scores for each specimen were pooled and the microleakage scores for each

Table 1 Descriptive statistics and comparisons of mesial and distal microleakage scores for each of the three groups (n = 20) between composite–enamel and composite–wire interfaces (mm).

Interface	Group	Side	Mean	Standard deviation	Minimum	Maximum	*P* value (significance)
Composite–enamel	Transbond LR	Mesial	0.05	0.15	0.00	0.50	0.799 (NS)
		Distal	0.03	0.11	0.00	0.50	
	ACP-containing adhesive with primer	Mesial	0.40	0.53	0.00	1.50	0.253 (NS)
		Distal	0.38	0.46	0.00	1.50	
	ACP-containing adhesive without primer	Mesial	0.13	0.22	0.00	0.50	0.925 (NS)
		Distal	0.13	0.28	0.00	1.00	
Composite–wire	Transbond LR	Mesial	0.88	0.63	0.00	2.00	0.602 (NS)
		Distal	0.63	0.43	0.00	2.00	
	ACP-containing adhesive with primer	Mesial	1.63	0.72	0.50	3.00	0.841 (NS)
		Distal	1.70	0.62	0.50	3.00	
	ACP-containing adhesive without primer	Mesial	1.23	0.91	0.50	3.00	0.718 (NS)
		Distal	1.30	0.85	0.50	3.00	

ACP, amorphous calcium phosphate; NS, not significant.

group and interface was obtained by calculating the mean of the mesial and distal microleakage scores.

Descriptive statistics and the results of statistical tests for microleakage between the composite–enamel and composite–wire interfaces are shown in Table 2. Kruskal–Wallis analysis of variance revealed statistically significant differences among the investigated groups for both interfaces ($P < 0.001$). Therefore, the null hypothesis was rejected. All mean microleakage scores at the composite–wire interface were higher than those at the composite–enamel interface. Multiple comparisons showed statistically significant microleakage differences between groups 1 and 2 at the composite–enamel and composite–wire interfaces ($P < 0.001$). Significant differences were observed between groups 2 and 3 at the composite–enamel and composite–wire interface ($P < 0.05$). ACP-containing adhesive used with primer showed the highest microleakage scores between the composite–enamel (mean: 0.39 ± 0.42 mm) and composite–wire (mean: 1.66 ± 0.47 mm) interfaces.

Discussion

ACP-containing materials are a new class of 'smart' materials that self-activate in low pH oral environments and return to a latent state when pH returns to normal (Dunn, 2007). Skrtic *et al.* (2004a) demonstrated that ACP accelerates the tooth's natural calcium phosphate remineralization process to prevent demineralization which can result from microleakage or poor oral hygiene. This is important in orthodontics because when a problem arises during bonding, seepage, and leaking of fluids and bacteria between composite–enamel interfaces is possible. ACP-containing materials might compensate for this demineralization process which can cause potential white spot lesions.

Sudjalim *et al.* (2007) evaluated the effects of sodium fluoride (NaF) and 10 per cent casein phosphopeptide–ACP (CPP–ACP) on enamel demineralization adjacent to orthodontic brackets and found that application of CPP–ACP, NaF, or CPP–ACP/NaF significantly prevented enamel demineralization when orthodontic composite resin was used for bonding. ACP-containing orthodontic adhesives are claimed to reduce the prevalence of white spots around orthodontic appliances and may be an adjunct in the prevention of demineralization especially in patients where compliance is lacking (Foster *et al.*, 2008). Foster *et al.* (2008) suggested that ACP-containing adhesive can provide similar bond strengths to orthodontic adhesives already on the market and meet the bond strength recommendations of Tavas and Watts (1984). Although there is a growing body of evidence to support the remineralizing potential and effectiveness of ACP, there is concern over the physical and mechanical properties of these materials. No identical studies were found that have compared the microleakage under FSWRs bonded with a ACP-containing orthodontic composite and a conventional resin-based lingual retainer composite.

It has been reported that detachment at the composite–wire interface and abrasion of composite over the retainer wire are reasons for failure of lingual retainers (Bearn, 1995). On the other hand, microleakage may be another reason for the failure which, in turn, is thought to be a major cause of white spot lesions (James *et al.*, 2003; Arikan *et al.*, 2006) through leaking of bacteria, fluids, and ions between the composite and tooth surface. *In vitro*, microleakage is commonly determined to detect bond failure at the enamel–sealant interface through dye penetration. This failure can be due to polymerization shrinkage or different linear coefficients of thermal expansion from hard tooth substances and resin materials (Celiberti and Lussi, 2005). Thermal cycling is widely used to simulate temperature changes in the mouth, generating successive thermal stresses at the tooth–resin interface. In restorative dentistry, Kubo *et al.* (2001) investigated the microleakage of self-etching primers after thermal and flexural load

Table 2 Total microleakage comparisons between the composite–enamel and composite–wire interfaces for each of the three investigated groups, $n = 40$ (mm).

Interface	Group	Mean	Standard deviation	Minimum	Maximum	Kruskal–Wallis test	Multiple comparisons	
							Group 2	Group 3
Composite–enamel	Transbond LR	0.04	0.09	0.00	0.25		0.000***	0.951 (NS)
	ACP-containing adhesive with primer	0.39	0.42	0.00	1.50	0.000***		0.011*
	ACP-containing adhesive without primer	0.13	0.21	0.00	0.75			
Composite–wire	Transbond LR	0.75	0.41	0.25	2.00		0.000***	0.096 (NS)
	ACP-containing adhesive with primer	1.66	0.47	1.00	2.75	0.000***		0.020*
	ACP-containing adhesive without primer	1.26	0.78	0.50	3.00			

ACP, amorphous calcium phosphate; NS, not significant; $*P < 0.05$; $***P < 0.001$.

cycling and found that the marginal integrity of self-etching primers did not deteriorate even after thermal cycling (5000–10 000 cycles) and flexural loading. Similarly, several researchers indicated that an increase in the number of thermal cycles is not related to an increase in microleakage of restorations (Bedran-de-Castro *et al.*, 2004; Celiberti and Lussi, 2005). Therefore, thermocycling was not performed in the current study.

Dye penetration was chosen to determine microleakage of the bonded specimens. This is the most commonly used method to assess microleakage of dental materials (Taylor and Lynch, 1992). It is easy to perform, fast, and economical, but the shortcoming of the technique is subjectivity of reading the specimens (Alani and Toh, 1997). In the present study, all specimens were evaluated by two operators on two occasions to determine measurement error. Kappa scores were found to be high with all values greater than 0.85. It is important to note, however, that the assessment was made only at the mesial and distal aspect of each tooth. These sites were selected because they were easily identifiable on each specimen. Microleakage, however, may not be similar at other sites on a bonded tooth although restorative dental studies have assumed that one site assessment is representative of the whole tooth (Gale *et al.*, 1994).

Descriptive statistics and comparisons of mesial and distal microleakage at the composite–enamel interfaces of the three groups showed little or no microleakage differences. These findings were not statistically significant (Table 1). However, all groups exhibited some microleakage, highlighting the existence and importance of microleakage under lingual retainer composites.

Bonding to enamel is stronger and more stable than bonding to dentine, and leakage along enamel is reduced or completely prevented (Santini *et al.*, 2004). Enamel etching with phosphoric acid results in lower microleakage, improved tag formation, and good quality and longer tags compared with self-etching primer (Celiberti and Lussi, 2005). In the present research, lower microleakage scores at the composite–enamel interface may be attributed to the positive effect of acid etching. Microleakage at the enamel–composite interface was not a major concern in any of the groups tested when acid etching was performed.

However, ACP-containing adhesive applied with primer onto the etched enamel surface showed higher microleakage than conventional composite and this difference was statistically significant. These microleakage values for Aegis Ortho, while significant, were less than 0.5 mm. This may be due to the cured primer layer between the enamel and ACP-containing composite.

Similar to the orthodontic lingual retainer adhesive (i.e. Transbond LR), while the manufacturers of the ACP-containing adhesive produced a composite paste with a more flowable consistency that can readily penetrate over the lingual retainer wire and enamel surface or the mesh of the bracket base for orthodontic purposes, the microleakage values for this adhesive between composite–wire interface was higher than Transbond LR. It is stated in the literature that the most common failure type for lingual retainers is detachment at the wire-adhesive interface (Bearn, 1995). According to the results of present study, statistically significant microleakage at this interface may be interpreted as a factor for failure.

Conclusions

1. The amount of microleakage at the wire–composite interface was higher than that at the enamel–composite interface for all groups. No or little microleakage was observed at the composite–enamel interface, for any of the tested composites.
2. ACP-containing composite used with primer presented significantly higher leakage at the composite–wire interface, while conventional lingual retainer composite showed lower results.

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