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ORIGINAL ARTICLE

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Microleakage between composite/wire and composite/enamel interfaces of flexible spiral wire retainers: direct versus indirect application methods

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Structured Abstract

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Objective – The aim of this *in vitro* study was to compare the microleakage of flexible spiral wire retainers (FSWR) at composite/wire and composite/enamel interfaces produced by an indirect application method to that of a conventional direct application method.

Materials and Methods – Forty freshly extracted human mandibular incisor teeth were randomly divided into two equal groups. Group 1 was bonded directly according to the manufacturer's recommendations. Group 2 consisted of 20 teeth bonded indirectly with Transbond LR as the adhesive and Sondhi Rapid Set A/B Primer (3M Unitek, Monrovia, CA, USA), a filled resin primer. After bonding, specimens were further sealed with nail varnish, stained with 0.5% basic fuchsine for 24 h, sectioned and examined under a stereomicroscope that measured microleakage at the composite/wire and composite/enamel interfaces from both mesial and distal margins. Statistical analyses were performed using Wilcoxon and Mann–Whitney *U*-tests with Bonferroni correction.

Results – Statistical comparisons indicated that no statistically significant differences were observed between composite/wire and composite/enamel interfaces for direct vs. indirect application procedures (Direct method $p = 0.630$ and Indirect method $p = 0.930$). Comparisons of the microleakage scores between direct and indirect FSWR application groups at composite/wire and composite/enamel interfaces indicated no statistically significant microleakage differences at mesial or distal margins (Composite/enamel interface $p = 0.361$ and Composite/wire interface $p = 0.270$).

Conclusion – The type of FSWR application procedures (direct vs. indirect) did not significantly affect the amount of microleakage at the enamel/composite/wire complex.

Key words: biomaterials; *in vitro*; orthodontic retainers

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Introduction

Various methods have been proposed for retaining the lower labial segment after removal of fixed orthodontic appliances (1). The first retainers proposed were based on banded fixed appliances; then removable retainers were advocated. With the evolution of acid etching in orthodontic practice, bonding provided new retention alternatives. Lingual retainers were being made from smooth round or rectangular wires, but Zachrisson (2) reported on the structural advantages of flexible spiral wire retainers (FSWR). The proposed advantages of using multistrand wire are that the irregular surface offers increased mechanical retention for the composite without the need for placing retentive loops (1), and that the flexibility of the wire allows physiological movement of the teeth (3).

As an alternative to multistrand wire, the use of fourth generation retainers (2) and polyethylene fibre materials (4) has been developed, but multistrand wires remain the most popular choice for retainers.

Now, there is general agreement on the necessity of FSWR to prevent relapse in many patients after active orthodontic treatment (5). Several methods for delivering FSWR have been introduced (4–6). Mainly, direct and indirect methods available for placing FSWR (7, 8).

When placing a retainer with a direct bonding technique, various materials and methods are used to fixate the wire, including dental floss (1), elastics (9), ligature wire, wires tack-welded to the retainer wire, and finger pressure (10). However, bonding a lingual retainer is still challenging because it is time consuming and risks contamination from saliva and moisture and risks changes in wire position, which can cause bonding failure. To avoid these problems, the use of indirect techniques has been described (11).

The indirect method has several advantages compared to the direct method. These are accurate placement of attachments, improved patient comfort, less chair time for patients and prevention of the etched surface from contamination (12). Despite these advantages, there are disadvantages that include technique sensitivity, additional set of impressions needed, increased laboratory time and risk of adhesive leakage to gingival embrasures (12).

Årtun (3) investigated the potential caries and periodontal reactions associated with long-term use of different types of bonded lingual retainers and concluded that there is a tendency for plaque and calculus to accumulate along the retainer wires; this tendency seemed to increase with time. Årtun and Brobakken (13) also indicated that this plaque accumulation can often promote subsequent acid production leading to decalcification and an alteration in the appearance of the enamel surface.

The polymerization shrinkage of the adhesive material may cause gaps between the adhesive material and the enamel surface (14). Gap formation contributes to microleakage, permitting the passage of bacteria and oral fluids into the oral cavity (15). Microleakage beneath composite is particularly important in orthodontics especially for lingual retainer adhesives, as they are exposed to the oral cavity and intended to serve in the mouth for a long period of time.

No research could be found in the literature that has investigated and compared the microleakage of FSWR when bonded with different application methods (direct vs. indirect). Therefore, the aim of this *in vitro* study was to compare the microleakage of FSWR between composite/wire and composite/enamel interfaces that were indirectly applied to that of a conventional direct FSWR application method. For the purposes of this study, the null hypothesis assumed that there were no statistically significant differences between the microleakage of an enamel/composite/wire complex in either the direct or indirect application procedures.

Materials and methods

Sample preparation

Forty human mandibular incisor teeth, extracted for periodontal considerations, were collected during 1 month. The extracted teeth were stored in distilled water until use (maximum 1 month). Immediately before bonding, teeth were cleaned with scaler and pumice to remove soft tissue remnants, calculus and plaque. Specimens were randomly assigned to two equal groups on the basis of the application procedures.

Multi-stranded PentaOne® wire (Masel Orthodontics, 2701 Bartrarn Road, Bristol, PA, USA) 0.0215′ in diameter was used in both groups. Wires were cut into 10 mm lengths to ensure standardization, and the wires were bent to fit the lingual curvature of incisor teeth.

Group 1 was bonded directly according to manufacturer's recommendations. Twenty mandibular incisor teeth were separated; a 37% phosphoric acid gel (3M-Dental Products, St. Paul, MN, USA) was used to etch them for 15 s. The teeth were then rinsed with water from a 3-in-1 syringe for 30 s and dried with an oil-free air source for 20 s. After surface preparation, the liquid primer Transbond XT (3M Unitek) was applied to the etched surface as a thin uniform coat. The primer was not cured according to the manufacturer's instructions. Using an adhesive dispensing gun, a conventional orthodontic lingual retainer composite, Transbond LR (3M Unitek) was placed, shaped and cured.

Group 2 consisted of 20 teeth bonded indirectly with Transbond LR as the adhesive and Sondhi Rapid Set A/B Primer (3M Unitek), a filled resin primer. The teeth were then mounted in cold cure acrylic. An alginate impression was made of the mounted teeth and poured out in hard orthodontic stone (Snow White Stone; Heraeas Kulzer, Hanau, Germany). The working models were allowed to set overnight, and a layer of Al Cote separating medium (Dentsply Trubyte, York, PA, USA) diluted with water at a 1:1 ratio was placed on each model and allowed to dry for 20 min. Retainers were placed on the working model with Transbond LR (3M Unitek), and the excess was removed with a hand instrument. Then the model was placed into a Triad light-curing unit (Dentsply Trubyte) at three angles to the light source and cured for a total of 10 min. A transfer tray was fabricated using a Biostar (Great Lakes Orthodontics, Tonowanda, NY, USA) unit to vacu-form a 1 mm thick layer of Bioplast (Great Lakes Orthodontics Ltd.), over layered with a 1 mm thick layer of Biocryl (Great Lakes Orthodontics). The transfer tray was carefully removed from the working model and placed back into the Triad machine for 1 min with the adhesive bases facing the light source. The adhesive bases were scrubbed with a toothbrush under running water and blown dry with oil-free air. Enamels in group 2 were prepared the same as group 1. While the liquid primer Transbond XT (3M-Unitek) was applied to the etched surface in group 1, the Sondhi Rapid Set Primer used in group 2. After etching and drying the teeth as described earlier, a thin layer of primer A was painted on each tooth, and a thin layer of resin B was painted on each adhesive base. The transfer tray was placed and held with finger pressure for 30 s and then left on the teeth without any pressure for 2 min before removal of the tray.

Microleakage evaluation

Prior to dye penetration, the apices were sealed with sticky wax, rinsed in tap water, and air-dried nail varnish was applied to the entire surface of the tooth except for approximately 1 mm away from the composite bulk. To minimize dehydration of the restorations, the teeth were replaced in water as soon as the nail polish dried. The teeth were immersed in 0.5% solution of basic fuchsine for 24 h at room temperature. After being removed from the solution, the teeth were rinsed in tap water, and the superficial dye was removed with a brush and dried.

Each specimen was sectioned in a transverse plane (parallel to the lingual retainer wire) just above the wire with a low speed water-cooled diamond saw (Isomet; Buehler, Lake Bluff, IL, USA). The specimens were evaluated first under a stereomicroscope (×20 magnifications) (SZ 40; Olympus, Tokyo, Japan) for dye penetration along the composite/enamel interface. Then lingual retainer wires were gently removed from the composite bulk, and the dye penetration between the composite/wire interface in both the mesial and distal direction was also evaluated under a stereomicroscope. Microleakage was determined by direct measurement using an electronic digital calliper (Mitutoyo, Miyazaki, Japan) (Fig. 1) and recording the data to the nearest value as a range 0.5–5 mm.

Statistical analysis

For each composite interface (composite/wire and composite/enamel), the microleakage scores were obtained by measuring the mesial and distal scores. After the statistical evaluation of mesial and distal leakage for each specimen, the score for each group was obtained by measuring the mean of mesial and distal microleakage scores.

Statistical analysis was performed using Wilcoxon and Mann–Whitney *U*-tests with Bonferroni correction (Statistical Package for Social Sciences, Vers.13.0; SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $\alpha = 0.05$.

For evaluating the intra-examiner agreement, the measurements were performed by one examiner (H.E.) using the same specimens at two separate times, and Cohen's Kappa scores were determined.

Results

All Kappa scores for the assessment of the intra-examiner agreement were higher than 0.80 that implies

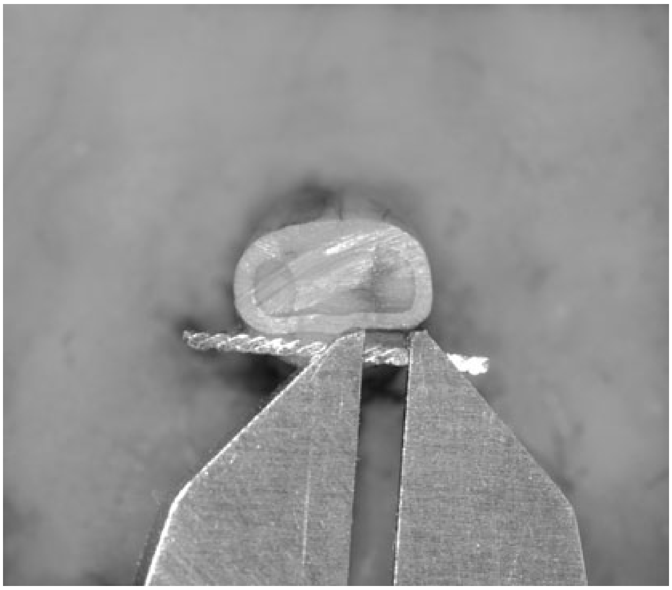

Fig. 1. Direct measurement with electronic digital calliper.

substantial agreement between the two observation periods (Table 1).

Comparisons of the microleakage scores between composite/wire and composite/enamel interfaces for direct and indirect application methods are shown in Table 2. No statistically significant differences were observed between composite/wire and composite/enamel interfaces for both lingual retainer bonding methods.

Descriptive statistical values and comparisons of the microleakage scores for two application methods are shown in Table 3. Statistical comparisons of the microleakage scores between two groups at composite/wire and composite/enamel interfaces indicated that the type of FSWR application method did not significantly affect the amount of microleakage at the mesial or distal margins of the composite/wire and composite/enamel interfaces (Composite/enamel interface $p = 0.361$ and Composite/wire interface $p = 0.270$). Therefore, the null hypothesis could not be rejected.

***Table 1.* Intra-examiner Kappa scores for assessment of microleakage**

	Kappa scores			
	Mesial side		Distal side	
Interface	Direct method	Indirect method	Direct method	Indirect method
Enamel/Composite	0.85	0.91	0.85	0.80
Wire/Composite	0.93	0.95	0.99	0.96

Discussion

Al-Sehaibany et al. (16) have investigated bond strength values of lingual retainers bonded by a modified bonding technique compared with the conventional direct technique. In that study, the modified bonding technique showed higher shear bond strength compared to the direct bonding technique. Uysal et al. (17) evaluated the shear bond strength and fracture mode difference between newly developed amorphous calcium phosphate (ACP)-containing orthodontic adhesive and conventional resin-based composite material and showed that the ACP-containing adhesive decreased the bond strength of lingual retainers.

In recent years, microleakage under orthodontic brackets (18, 19), molar bands (20) and lingual retainers (21, 22) became an important issue, and many studies have been published related to this topic. Uysal et al. (21) evaluated microleakage under canine to canine lingual retainers bonded with three different composite types (Transbond XT, Transbond LR and Venus Flow) and found no statistically significant microleakage differences among the groups. In another study, Uysal et al. (22) determined that the amount of microleakage at the composite/wire interface was significantly greater than that at the composite/enamel interface of FSWR. A review of the literature indicated that no studies have compared the effect of different FSWR application methods (direct vs. indirect) on the amount of microleakage in an *in vitro* study design.

In restorative dentistry, microleakage is a phenomenon of the diffusion of organic or inorganic substances into a tooth through the interface between the restorative material and the tooth structure (23). Øgaard et al. (24) have shown that visible white spot lesions can develop within 4 weeks, and according to Gladwin and Bagby (25), microleakage increases the likelihood of recurrent caries and post-operative sensitivity. From an orthodontic perspective, it is possible to interpret this fact as supportive of the formation of decalcifications or caries between the composite and enamel interface (18). It is also likely that microleakage under the

Table 2. **Comparison of the microleakage scores between composite⁄wire and composite⁄enamel interfaces separately for direct vs indirect application procedures**

Method	Interface	Descriptive values (mm)				Percentiles			Statistical comparison
		Mean	SD	Minimum	Maximum	25th	50th (median)	75th	*p*-value
Direct	Composite⁄Enamel	0.11	0.20	0.00	0.50	0.00	0.00	0.19	0.630 NS
	Composite⁄Wire	0.02	0.06	0.00	0.25	0.00	0.00	0.00	
Indirect	Composite⁄Enamel	0.09	0.18	0.00	0.50	0.00	0.00	0.19	0.930 NS
	Composite⁄Wire	0.48	1.01	0.00	4.00	0.00	0.00	0.69	

Table 3. **Comparison of microleakage scores between direct and indirect application methods at composite⁄wire and composite⁄enamel interfaces**

Interface	Method	N	Descriptive values (mm)				Statistical comparison
			Mean	SD	Minimum	Maximum	*p*-value
Composite⁄Enamel	Direct	20	0.11	0.20	0.00	0.50	0.361 NS
	Indirect	20	0.48	1.01	0.00	4.00	
Composite⁄Wire	Direct	20	0.02	0.06	0.00	0.25	0.270 NS
	Indirect	20	0.09	0.18	0.00	0.50	

N, sample size.

composite holding the retainer wire may result in failure of the FSWR.

The most common failure type is detachment at wire and composite interface because of insufficient adhesive over the wire (10). Oesterle et al. (26) have investigated the effect of various wire surface treatments on bond strength values, and they indicated that sandblasting a stainless steel wire significantly increases the strength of the composite⁄wire bond. Similar to the composite⁄wire interface, the seeping and leaking of fluids and bacteria between the wire and composite interface may cause failure (25). Thus the investigation of microleakage between composite⁄wire interfaces might be an important topic for assessing the clinical success of treatments with lingual retainers.

Radlanski and Zain (27) have investigated the effect of different lingual retainer wires and different composites on bond strength values. They found that the twisted Dentaflex wires bonded with Tetric Flow attained the highest bond strength; nevertheless, there is no significant difference at the selected wires (Dentaflex® co-axial 0.018′, Dentaflex® multistranded 0.018′ and Respond® Dead Soft straight, length 0.0175′). Penta-One® 0.0215′ wire is most commonly used in orthodontics for lingual retainer fabrication (28), and a study by Bearn et al. (29) showed that an increased diameter from 0.0175′ to 0.0215′ for wire type increased the force required to pull the wire out from the composite. Therefore, 0.0215′ Penta-One® wire was chosen in this study.

Several techniques have been introduced to assess microleakage around dental restorations. The easiest and most commonly used methodology involves exposure of the samples to a dye solution and then viewing cross sections under a light microscope (30). To evaluate the relevance of a leakage test, the effective size of oral bacteria must be considered. Because of the range of bacteria sizes, dyes such as methylene blue and fuchsine are realistic agents to identify the presence of a clinically relevant gap (31). Dye penetration was chosen for this study because it provided a simple, relatively cheap, quantitative and comparable method of evaluating the microleakage of different lingual retainer bonding methods (30).

Arikan et al. (18) preferred a scoring method for microleakage evaluation: score 0 = no dye penetration between the bracket-adhesive or the adhesive-enamel interface, score 1 = dye penetration restricted to 1 mm of the bracket-adhesive or adhesive-enamel interface, score 2 = dye penetration into the inner half (2 mm) of the bracket-adhesive or adhesive-enamel interface, score 3 = dye penetration into 3 mm of the bracket-adhesive or adhesive-enamel interface. However, other investigators preferred a direct measurement method, and they used an electronic digital calliper for microleakage evaluation (19–22). In this study, we used direct measurement using an electronic digital calliper because we thought that this method was more sensitive than others.

In vitro microleakage is commonly assessed to detect bond failure at the enamel sealant interface through dye penetration. This failure can be because of polymerization shrinkage or different linear coefficients of thermal expansion from tooth hard substances and resin materials (32). Thermal cycles are widely used to simulate temperature changes in the mouth, generating successive thermal stresses at the tooth-resin interface. Several studies indicated that an increase in the number of thermal cycles was not related to an increase in microleakage of restorations (33). Therefore, thermocycling was not performed in this study.

White et al. (34) found that the type of cementing agent used for bonding has a bearing on microleakage. Ziskind et al. (35) indicated that the flowable composite resin presents remarkable flow characteristics compared to a restorative composite resin. The composition, viscosity and other special characteristics of cementing agents may affect the degree of leakage. Sondhi Rapid Set adhesive contains approximately 5% fine particle fumed silica fibre that increases viscosity (12). Piwowarczyk et al. (36) found that the adhesive that contains fumed silica fibre has lower microleakage scores than the others. So, we expected that the direct bonding group would show higher microleakage than the indirect bonding group. However, this expectation was not met.

For restorative dentistry, the shrinkage as a result of the polymerization process is greater for direct insertion in a cavity when the direct technique is used, than when a resinous cement layer is used to fix the indirect inlay. This fact results in a greater magnitude of stress in the gingival wall, thus facilitating microleakage. Milleding (37) reported that indirect inlay composite restorations result in less microleakage than direct composite resins. Liberman et al. (38) found that the indirect procedure resulted in a significantly reduced microleakage when compared to that produced by the semi-direct inlay technique. Alavi and Kianimanesh (39) reported that, when bonding agents are properly applied, there is no advantage to the indirect technique in small class V cavities. From an orthodontic perspective, bonding of FSWR is a little different. It is thought that the polymerization shrinkage of adhesive material in orthodontics is probably an advantage compared with the materials used in restorative dentistry. This is because the adhesive layer is very thin, and there is usually an excess of resin at the edges of the adhesive area so that some of the shrinkage is absorbed. In addition, Oesterle et al. (40) showed that shrinkage will pull the bracket closer to teeth during the bonding procedure. In this study, we found that microleakage scores of the direct FSWR application method were similar to the indirect method. We thought that the reason for similar microleakage scores between the direct and indirect group is because the composite shrinks the retainer closer to the teeth.

In this study, microleakage under the lingual retainer, which may initiate calculus formation or white spot lesions under the bonding area, was not accelerated by changing the application method (direct vs. indirect). In this study, the null hypothesis could not be rejected because the type of bonding method did not affect the amount of microleakage.

Conclusions

The type of bonding method (direct vs. indirect) did not significantly affect the amount of microleakage of the enamel-composite-wire complex.

Clinical relevance

Direct bonding of a lingual retainer is time consuming and risks contamination from saliva and moisture and risks changes in wire position. To avoid these problems, indirect bonding techniques can be used. Any difference in microleakage is important because retainers are used for a long time. This study showed that the type of application methods (direct vs. indirect) did not affect the amount of microleakage at the enamel/composite/wire complex. So, indirect bonding methods can be used with assurance.

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