Comparison Between Two Clinical Procedures for Bonding Fiber Posts into a Root Canal: A Microscopic Investigation

Alessandro Vichi, DDS, Simone Grandini, DDS, and Marco Ferrari, MD, DDS, PhD

The purpose of this study was to evaluate the influence of two brushes used as carriers of a primer-adhesive solution as to the formation of resin tags, adhesive lateral branches, and a hybrid layer when used to bond translucent fiber posts. Twenty endodontically treated teeth, extracted for periodontal reasons, were used. The samples were randomly divided into two groups of 10 samples each (Group 1: Microbrush + Scotchbond 1 + Rely X ARC resin cement; Group 2: small plastic brush + Scotchbond 1 + Rely X ARC resin cement). The adhesive system and resin cement were used strictly following manufacturers’ instructions. The priming-adhesive solution of the one-bottle system was light-cured before placing the resin cement and the post. Twenty translucent fiber posts were used. After luting procedures, root samples were processed for SEM observations. The adhesive system showed a resin dentin interdiffusion zone (RDIZ), resin tag, and adhesive lateral branch formation. Microscopic examination of restored interfaces of group 1 showed a higher percentage (p < 0.05) of RDIZ than those found in samples of group 2. In group 1 samples, RDIZ morphology was well detectable and uniform in all thirds of the root canals. In group 2, RDIZ was not visible in the apical third. No statistically significant differences were found among the two groups coronally and at the middle third, but the apical third of group 1 showed significantly more resin tag formation than group 2. The characteristic reverse cone shape of resin tags was always noted in the coronal and middle third of the root canals of both groups and in the apical third of group 1. In the apical third of group 2 root canals, the resin tags showed a less uniform morphology and a shorter length than those found in the other observed thirds.

Endodontically treated teeth with defective clinical crowns very often need to be restored with a post and core as a foundation for the final restoration (1, 2). In the last few decades, cast posts have been the most commonly used form of restoration for these teeth. Unfortunately, several disadvantages associated with conventional cast post-and-cores have been reported, such as loss of retention of the post or the crown, a potential for post and root fracture, and a risk of corrosion when different metals were used in the system (1–4). Although several factors are involved, some of these failures can be related to the mechanical properties of the posts (5–7). In particular, root fractures have been mainly correlated to the shape and length of the post (1, 2, 4).

Thus, the use of the frictionless-bonded post technique in combination with fiber posts has been advocated to reduce the risk of root fracture from the wedging effect of metallic posts (7, 8). Recently, the use of adhesive systems for luting fiber posts has increased in popularity, and resin-cement materials have been proposed for use in combination with an acid-etching technique and adhesive system and a luting resin cement and fiber posts (7, 9, 10).

The fiber post offers several favorable characteristics: (a) the modulus of elasticity of a fiber post is similar to that of dentin (7, 9); (b) the post can be cemented with an adhesive technique avoiding the development of friction between the post and root canal walls (7, 9, 10); (c) fiber translucent posts exhibit high fatigue and tensile strength and have a modulus of elasticity (stiffness) comparable with that of carbon and quartz fiber posts (7); and (d) their chemical nature is compatible with the Bis-GMA resins commonly used in bonding procedures.

Use of the latest generation of adhesive systems involves etching, removal of the smear layer, demineralization of the dentin, and exposure of a fine network of collagen fibrils (11). Infiltration of this network with resin permits formation of a hybrid layer, resin tags, and adhesive lateral branches, thus creating a micromechanical retention of the resin to the demineralized substrate (12, 13).

Although bonding into root canals might be difficult because of the handling characteristics of the adhesive system, the anatomy of the root, tooth position, presence of residual-coronal tissues, light-curing technique, clinical experience of the operator, and etc., recent clinical studies have shown the efficacy of fiber posts when luted with adhesive materials (14–16).

The aims of this clinical report were (a) to evaluate the effectiveness of the Scotchbond (SB1; 3M, St. Paul, MN) adhesive
system in combination with Rely X (3M) ARC resin cement in formation of resin tags, adhesive lateral branches, and a hybrid layer when used to lute esthetic fiber posts under clinical and laboratory conditions; and (b) to test the null hypothesis that the type of carrier of primer-adhesive solution cannot affect bonding mechanism to root-etched dentin.

MATERIALS AND METHODS

Twenty monoradicular endodontically treated teeth, extracted because of periodontal problems, were selected for this study. The coronal part of the samples was removed at the CEJ. Then, the teeth were endodontically instrumented at a working length 1 mm from the apex to a #35 master apical file. A step-back technique was used with stainless-steel K-files (Union Broach, New York, NY), Gates Glidden drills #2 to #4 (Union Broach), and 2.5% sodium hypochlorite irrigation. The prepared teeth were obturated with thermoplasticized, injectable gutta-percha (Obtura, Texceed Corp., Costa Mesa, CA) and resin sealer (AH-26, DeTrey, Zurich, Switzerland). The samples were randomly divided in two groups of 10 samples each, and luting procedures were performed (Table 1).

**Group 1: SB1M Applied Using a Microbrush (SB1M)**

The root canal walls were enlarged with low-speed burs provided by the manufacturer of the posts; the depth of the post space preparation was 9 mm. The root canal walls were etched with 35% phosphoric acid for 15 s, washed with water spray, and gently air-dried. The excess water was removed from the post space by using paper points. SB1 primer adhesive was then applied with a microbrush tip (Fig. 1), air-dried, and the pooled primer remaining in the post space was removed by using a paper point. The adhesive was light-cured for 20 s by placing the light source at the top of the root canal, followed by placement of Rely X ARC according to the manufacturer’s instructions. The diameter of the (esthetic) translucent fiber post (RTD, France) used was 1.1 mm. The cement was applied into the root-canal space by means of a lentulo and onto the post surface, and the post was then inserted into the canal. The cement was allowed to set by light curing through the post for 20 s, after which crown build-up was performed with Z250 resin composite (3M).

**Group 2: SB1 Applied Using a Brush**

A similar procedure to that described for group 1 was carried out. The primer-adhesive solution was applied into the root-canal preparation by using the small plastic brush (Fig. 2) provided by the manufacturer of the adhesive materials (3M).

![Fig. 1. The thin microbrush can penetrate into the root-canal preparation.](image)

After being restored, the sample teeth from both groups were stored in water for not more than 10 days and then processed for microscopic investigation.

**Resin Dentin Interdiffusion Zone Observations**

The root samples were split-fractured along the long axis of the tooth, in a mesial-distal direction, and one section of each root was gently decalcified (35% phosphoric acid was applied for 60 s and the sample was then washed and gently air-dried) and deproteinized (the sample was immersed in a 2% sodium hypochlorite solution for 120 s) to evaluate hybrid-layer formation. The other section was kept in a solution of 30% HCl for 24 h to completely dissolve the dental substrate and to detect resin tag and adhesive lateral branch formation. After being extensively rinsed with water, the two specimens were gently air-dried, sputter-coated with gold (Edwards Ltd, London, UK), and observed with a scanning electron microscope (Philips 515, Philips Co., Amsterdam, The Netherlands) at different magnifications, so that the extent, morphology, and thickness of the acid- and NaOCl-resistant resin-infiltrated layer and morphology of the resin tags could be examined and documented.

The following aspects were evaluated by scanning electron microscope:

<table>
<thead>
<tr>
<th>TABLE 1. Bonding-luting procedures</th>
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<tr>
<td><strong>Group</strong></td>
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<td>1</td>
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<td>2</td>
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- a = dentin conditioning with phosphoric acid; b = primer-adhesive application with a microbrush; c = primer-adhesive application with a plastic brush (3M); d = light-curing; e = mixing resin cement; f = cement application into root canal with a lentulo drill; g = removing resin excess with a small brush; h = light curing through the translucent fiber post.
1. The formation and uniformity of the resin dentin interdiffusion zone (RDIZ) along the entire length of the adhesive interface (Fig. 3);
2. The presence or absence of gaps: (a) inside the adhesive layer; (b) between the adhesive and resin-cement layer; (c) inside the resin cement layer; (d) between the adhesive and post.

Evaluation of Resin-Tag Formation

The second section of each sample was stored in 30% HCl for 24 h to completely dissolve the dental substrate and to detect resin-tag and adhesive, lateral-branch formation (Fig. 4). The samples were then processed for SEM observation as previously described. Serial, SEM photomicrographs at ×500 original magnification were taken of the canal walls at the 1-, 4.5-, and 8-mm levels. The serial photomicrographs were aligned to form a continuous horizontal examination strip at the three levels. Irrespective of the number of photomicrographs needed to form a complete strip, each strip was subdivided into eight assessment units. The density and morphology of the resin tags were then assessed.

The density and morphology of resin tags present at ×500 magnifications were graded between 0 and 3. A score of 0.0 was assigned where resin tags were not detectable. A score of 1.0 was recorded when a few short resin tags (resin plugs) were visible. A score of 2.0 was recorded where uniform resin-tag formation without lateral branches was noted. A score of 3.0 was recorded when long resin tags with lateral branches were uniformly evident.

RESULTS

The number of samples showing voids/bubbles within the resin cement and/or at the interface between resin cement and root walls is summarized in Table 2. The cement thickness varied in relation to the root canal shape for each individual tooth (Fig. 3). Between 40% and 50% of samples showed bubbles/voids within the cement. The adhesive-composite cement and composite cement-fiber post interfaces were substantially free of voids.
The results obtained regarding the presence of RDIZ under the SEM microscope are shown in Table 3. The ratio between the length of the RDIZ and the length of the observed interfaces is reported.

The samples from group 1 showed a uniform RDIZ formation (Fig. 5), including apically. In two samples, a discontinuous gap between the RDIZ and resin cement was observed.

The samples from group 2 showed a less uniform RDIZ formation, particularly in the apical third. A gap between RDIZ and resin cement was seldom noted (Fig. 6).

**Table 3. Scanning electron microscope observation of the RDIZ**

<table>
<thead>
<tr>
<th>Group</th>
<th>Overall Length of Observed Interface (m)</th>
<th>Length of Interface with RDIZ (m)</th>
<th>% of interface with RDIZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: SB1M</td>
<td>26</td>
<td>23 (88%)*</td>
<td></td>
</tr>
<tr>
<td>2: SB1</td>
<td>28</td>
<td>22 (80%)*</td>
<td></td>
</tr>
</tbody>
</table>

*Superscript letters show statistically significant difference; p < 0.001.

**DISCUSSION**

Recently, scanning electron microscopic studies have clearly shown that the bonding mechanism of adhesive systems to root-dentin substrate is essentially of a micromechanical nature, based on infiltration of the demineralized surface and formation of resin tags and adhesive-lateral branches (11–13). Unfortunately, SEM evaluation did not permit collection of numeric data and consequently any statistical analysis. Only a few studies have reported the quantitative evaluation of morphological observations of root canals (10, 17, 18). In one study (10), RDIZ formation was evaluated by calculating the length of RDIZ formed immediately apical and immediately coronal to three notches made by a scalpel 2-, 5-, and 8-mm apically to the dentin-core junction. In this study, a similar evaluation of RDIZ formation was performed but along the entire adhesive interface of each sample and the data evaluated statistically. Also, the resin tags were recorded at horizontal bands around the posts, 1, 4.5, and 8 mm from the apices of the root-canal preparations (18). In this manner, it was possible to score and statistically analyze the data obtained from samples of two different groups.

The resin-tag network can be considered to result from an increase in the surface area made available for bonding by the effect of etching the dentin (11, 19), but not all areas exhibited an equal response to the etching procedure. In the group 2 samples, different resin-tag densities were noted at the three horizontal bands, whereas the group 1 specimens showed a more uniform resin-tag formation. This could be due to the fact that pressure during the bonding application would be maximal in the cervical region; and in the apical third, the pressure might be reduced, resulting in resin penetrating less deeply into the tubules, leaving the lateral branches unfilled. Another explanation of the differing densities and morphology of resin tags and adhesive lateral branches at the different regions of the root could be related to the
shape of the short plastic brush used for carrying the primer and/or primer-adhesive solutions into the root-canal space; the length of the bristles was approximately 4 to 5 mm, which may not have reached to the apical third (Fig. 2). The primer-adhesive solution may have penetrated the opened dentinal tubules due to its wettable property, but it might not have been enough to properly infiltrate the apical substrate. A very thin microbrush, as in group 1, that was able to penetrate deeply into a root-canal preparation was more predictable and useful (Fig. 1).

After light curing the bonding system from the coronal end of the canal, the dentin-bonding system tested could form a RDIZ that did not interfere with the post placement into the root canal. This is likely due to the fact that the one-step bonding system tested in this study produces a very low film thickness and has sufficient reactivity to the curing light that it can be polymerized by a light source placed at the access to the root canal. The presence of voids/bubbles within the resin cement might be mainly related to the cement characteristics and to the anatomy of the root samples. The anatomical variability of the root, and consequently the variable amount of resin cement and its three-dimensional distribution into the prepared canal space, could determine void formation. Another reason for the voids/bubbles present within the resin cement might be the need for mixing base and catalyst, incorporating air. Also, viscosity of the cement and placement technique might determine void and/or bubble formation.

Recently, a retrospective study of the clinical performance of fiber posts has been reported (20). Three types of fiber posts and four adhesive systems in combination with proprietary resin cements were tested, including Scotchbond MultiPurpose Plus (3M),

Table 4. Mean and median resin-tag formation scores recorded at 1-, 4.5- and 8-/mm levels of bonded posts

<table>
<thead>
<tr>
<th>Group</th>
<th>1-/mm Level (coronal third)</th>
<th>4.5-/mm Level (medium third)</th>
<th>8-/mm Level (apical third)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
</tr>
<tr>
<td>1: SB1M</td>
<td>2.905a</td>
<td>2.9</td>
<td>2.492a</td>
</tr>
<tr>
<td>2: SB1</td>
<td>2.921a</td>
<td>2.9</td>
<td>2.653a</td>
</tr>
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</table>

Group with the same letter did not show any statistically significant difference.
in combination with Opal luting composite, and Scotchbond 1 (Single Bond; 3M), in combination with Rely X ARC resin cement. The latter combination of adhesive materials showed only nine failures out of 252 luted posts. All the failures consisted of debonding of the post without any irreversible damage to the root. In these instances, the debonded posts were either reluted into the root canal or replaced by a new preparation. All the posts were luted by using a brush to carry the adhesive into the root canal. It might be speculated that by using a microbrush the bonding mechanism can be improved and consequently clinical debonding of the post without any irreversible damage to the root.

It can be concluded that resin-tag and hybrid-layer formation produced by SB1 in combination with Rely X ARC was evident, and it created a micromechanical interlocking with root-canal dentin. The null hypothesis of this study was rejected. Microbrushs were used, the bonding mechanism created between root-canal dentin and one-bottle system was uniform along canal walls of root-canal preparation.

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References