Translucent fiber post cementation using a light-curing adhesive/composite system: SEM analysis and pull-out test

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Summary Objectives. The performance of both light-curing and dual-cured adhesive/luting systems (as control), when used in combination with translucent fibre posts, was evaluated by means of pull-out test and scanning electron microscopy (SEM) observation.

Methods. Forty root canal treated teeth were randomly divided into two groups of 20 specimens each. Group 1 light-curing system: Excite and Tetric Flow; Group 2 dual cured system: All Bond 2 + RelyX ARC. Translucent, double taper fibre posts were used (2.1/1.4 mm diameter). The teeth were stored in NaCl 0.9% solution at 37 °C. A week later, the pull-out test was carried out on all specimens. Ten tested specimens for each group and their corresponding posts were processed for SEM observation. Statistical analysis was performed applying one-way analysis of variance (ANOVA) followed by T-test as post-hoc comparison at a significance level set at p < 0.05.

Results. There is no statistically significant difference (p > 0.05) between the light-curing system group (275.2 ± 58.9 N) and the dual cured one (301.4 ± 40.1 N). SEM observations confirm a good bond between the dentine and the post whatever the curing method employed.

Conclusions. Dual curing of the All Bond 2 + RelyX ARC system seems to be the most appropriate method since it allows to cure even those areas which would not be otherwise reached by light. On the other hand, in apical areas, the incomplete curing of the Excite + Tetric Flow system could improve the post adaptation and allow the achievement of both an improved apical seal and a more even distribution of the stress along the canal walls.

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Introduction

The use of fibre posts in the restoration of endodontically treated teeth has recently
increased in popularity. This is due to two main factors: first, fibre posts are ready to use, and therefore save time; second, some studies have demonstrated that their use reduces the risk of fracture since their modulus of elasticity is similar to that of dentine.

Since carbon fibre posts can jeopardize the aesthetic appearance of direct restorations, white and translucent fibre posts were introduced. Translucent fibre posts have high fatigue and tensile strength and their modulus of elasticity can be compared to that of dentine and of other fibre posts. Translucent fibre posts should allow light to be transmitted into the root canal. This would increase the conversion degree of dual-cured composite resins with a consequent improvement of their mechanical properties such as modulus of elasticity and hardness. However, the ability to transmit light through the post has still to be determined. The exclusive use of dual-cured or self-curing composites to lute fibre posts is therefore recommended.

Nevertheless, mechanical tests carried out in a recent pilot study show no remarkable difference between the use of light-curing and dual-cured composites in the cementation of translucent posts.

The aim of this study, which was carried out by means of a pull-out test and SEM observations, was to compare the performance of light-cure cement with a dual-cured adhesive/luting system (control group) in the root canal dentine when used to cement translucent fibre posts.

**Materials and methods**

Forty caries-free human maxillary anterior teeth, extracted due to periodontal problems, were selected for this study. These teeth were stored in 10% formaline solution at 4°C, and were used within 1 month after the extraction.

**Specimen preparation**

The crown was removed by cutting it at the amelocemental junction with a low speed diamond saw (Isomet 1000, Buhler, Lake Bluff, NY, USA). A metal post was inserted into the root canal in order to obtain a cutting surface perpendicular to the longitudinal axis. The root canals were mechanically enlarged by alternating Hero 6,4,2 endodontic files (Micro Mega SA, Geneva, Switzerland) operated at 400 rpm, and syringe irrigation with 2.5% NaOCl. The definitive preparations had a 6-degree taper (as a result of the instrument shape) and a diameter of 0.3 mm at the apex. The canals were then rinsed with water, dried with paper points (Kerr, Romulus, MI), and obturated with Pulp Canal Sealer E.W.T. (Kerr) using the continuous wave technique (System B, Analytic Technology, Redwood, USA). The root canal walls of each specimen were enlarged with low-speed drill tips provided by the manufacturer (RTD, France) with the fibre posts: the post space preparation was 9 mm in depth. The specimens were randomly divided into two groups of 20 specimens each (Table 1).

**Table 1** Tested materials and procedures of polymerisation.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Adhesive systems</th>
<th>Luting materials</th>
<th>Procedures of polymerisation</th>
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<tbody>
<tr>
<td>1.</td>
<td>Excite (Ivoclar-Vivadent)</td>
<td>Tetric Flow (Ivoclar-Vivadent)</td>
<td>Light cured for 60 s</td>
</tr>
<tr>
<td>2.</td>
<td>All Bond 2 (Bisco)</td>
<td>RelyX ARC (3M)</td>
<td>Self cured + light cured for 60 s</td>
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adhesive material was applied into the root canals with a microbrush (Plus Super Fine Roen). Excessive primer adhesive solution was removed with a paper point (Kerr) and then gently air-dried. Then a layer of bonding adhesive (included in All Bond 2 package) was applied into the root canals with a microbrush. Excess bonding adhesive solution was removed with a paper point. Finally, RelyX ARC composite base and catalyst were mixed for 10 s and applied as a layer on the fibre post surface. The fibre post was subsequently seated and the excess resin was removed. The polymerization of the resin cement was completed by light-polymerizing it through the post for 60 s (Astralis 10, Vivadent-Ivoclar pulse program for the first 20 s and high power for the following 40 s).

Translucent, double taper fibre posts (Light-Post N°3, RTD) were used (2.1/1.4 mm diameters). The specimens were stored in NaCl 0.9% solution at 37 °C for a week.

### Pull-out test specimen preparation

The pull-out test was carried out on 20 specimens for each group. The teeth were placed in acrylic resin blocks with the tooth/post extruding from the block horizontally. Parallelism between post, canal and resin block was obtained using a parallel meter (CL-MF2002S, Heraeus-Kulzer Inc.). Transverse cuts had been previously made on the root surface in order to increase resin retention. The pull-out test was performed along the long axis of the post and the tooth at a cross-head speed of 0.5 mm/min using a universal testing machine (Instron Inc., model 4301, High Wycombe, UK). The force required to dislodge each post was then recorded in Newton.

### Statistical analysis

Statistical analysis was performed applying one-way analysis of variance (ANOVA) followed by T-test (JMP Version 5.0 2002, SAS Institute Inc., Cary, NC, USA) as post-hoc comparison at a significance level set at $p<0.05$.

### SEM specimen preparation

Ten randomly selected specimens from each group, with their corresponding posts, were prepared for SEM observation. After the removal of the resin, the roots were longitudinally sectioned using a low speed diamond saw under water coolant. Each half was then smoothed under running water with 600 grit silicon carbide paper. One half of each specimen was treated with 15% EDTA (Largal Ultra, Septodont) for 60 s then rinsed with water and air-water spray for 30 s. In order to carry out a more correct analysis of the hybrid layer and of the resin tag formation, the other half of each specimen was partially deprived of its organic and mineral components. To this aim, the sectioned surface was treated using 37% $\text{H}_3\text{PO}_4$ (Total Etch, Vivadent-Ivoclar) for 120 s, then rinsed with water and air-water spray for 30 s. The specimens were subsequently immersed in NaOCl (7 ±2%) for 15 min, and rinsed again with tap water for 30 s.

The specimens were first dehydrated in alcohol-acetone and then the Critical Point Dry process was carried out (CPD 030, BAL-TEC AG, Balzers FL).

Subsequently, the specimens from each group were mounted on aluminum stubs coated with colloidal silver paint, and sputter-coated (SCD 005 BAL-TEC AG, Balzers FL) with 200 Å gold-palladium alloy. Each specimen was examined by SEM (Philips 515, Philips Co., Amsterdam, The Netherlands) at a 15 KV accelerating voltage. A computer program (Analysis, Soft Imaging System, GMBH) was used to convert microscope images.

### Results

#### Pull-out tests

Data from the pull-out tests are presented in Table 2. No statistically significant difference ($p>0.05$) between the light-curing system group and the dual cured group was found (Fig. 1).

#### SEM observations

SEM images of Group I specimens were similar to those of Group II specimens.

In all specimens ‘debonding’ mainly occurred at the dentine-cement interface and the extracted posts were almost entirely covered with a consistent resin cement layer (Fig. 2A). Nevertheless, very large voids were found in the apical third of some posts (Fig. 2B). Furthermore, both groups showed several small bubbles on the cement layer that

<table>
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<td>Groups</td>
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<td>EX + TF</td>
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<td>AB + RX</td>
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Means with similar superscript symbols indicate non-significant differences ($p>0.05$).
covered the apical and middle thirds of the posts (Fig. 3A). Large areas with many fractured resin tags were found on the post surface (Fig. 3B).

Some of the dentinal tubules that were visible on the dentinal walls appear to be obstructed by resin material (Fig. 4A), while others were open (Fig. 4B). It was possible to see some glass fibres that probably came off the post surface and were trapped in the cement residue (Fig. 5A–B).

**Discussion**

According to the results of this study, dual curing of the All Bond 2 + RelyX ARC system seems to be the most appropriate method since it allows even those areas which would not otherwise be reached by light to be cured. Consequently, cement acquires a higher conversion rate even in the most apical areas with an improvement of the mechanical
properties. This, however, involves a higher contraction stress and a higher modulus of elasticity as well as the possibility of a reduced bonding and the consequent loss of the apical seal. In addition, longer preparation times are required and it is generally difficult to completely fill the apical third of the canal root. Last but not least, the manual mixing procedure, which is necessary in the case of two-paste systems, could produce bubbles.

On the other hand, in apical areas, the incomplete curing of the Excite\textsuperscript{C} Tetric Flow system (the light radiation transmitted by the post is moderate and decreases as depth increases) could improve the post adaptation due to a lower contraction of the cement. Moreover, single-paste systems reduce the risk of bubbles to a greater extent than two-paste systems and allow the use of flowable composites, which are easier to apply inside the root canal, thus reducing the formation of voids.

The pull-out test showed that the bond strength in the specimens prepared using the EX\textsuperscript{C} TC light-curing system was only slightly inferior to that recorded in the specimens prepared with the AB\textsuperscript{C} RX dual cured system. However, no statistically significant differences were found between the two groups.

SEM observations of longitudinal sections and of extracted posts confirm a good bond both between the dentine and the cement as well as between the cement and the post regardless of the curing method employed.

Contraction stress induced by resin cement curing should also be taken into account. The composite flow is hindered by the confinement of the material bonded to the tooth in the pre-gel phase, and, as a result, contraction manifests itself as stress at the adhesive interface. There is a relationship between the configuration of the cavity and stress development. If the composite can shrink without any restriction within a cavity, no problems may be expected. When the contraction is hindered in three dimensions, the stress will be less compensated for by flow.\textsuperscript{6} Feilzer et al.\textsuperscript{7} developed the concept of the C-Factor, the ratio of the free and restrained composite surface area of a dental restoration. In general, an increasing rate of shrinkage stress development with an increasing C-value leads to a decreasing flow capacity.\textsuperscript{7} Whereas the C-factor typically varies from 1 to 5 in intracoronal restorations,\textsuperscript{7} it exceeded 200 in the cementation of endodontic posts to root canal dentine (the worst case scenario).\textsuperscript{8} Therefore, shrinkage stress in the confinement of the intact

**Figure 4** (A) Scanning electronic microscope image showing the canal wall of a Group 2 specimen, which was longitudinally sectioned and then treated using EDTA. A homogenous adhesive layer covers the dentinal surface and fills the dentinal tubules; (B) Scanning electronic microscope image showing the canal wall of a Group 2 specimen, which was longitudinally sectioned and then treated using EDTA. The dentine surface is not covered by any adhesive material and most tubules appear to be open.

**Figure 5** Scanning electronic microscope images showing the dentine-cement interface of a Group 1 specimen that was longitudinally sectioned and then treated using orthophosphoric acid and sodium hypochlorite (c: composite; d: dentine). Cement residue can be observed on the dentinal wall (A). The cement residue contains glass fibres (arrow) that probably came off the post surface (B).
root canal may exceed the cement–dentine bond strength, causing debonding of the cement from the dentine. The composition of the material is a factor that can influence the amount of shrinkage produced after polymerization. In fact, according to Hooke's rule, resin cements with a low modulus of elasticity produce low contraction stress.

As a result, in order to evenly distribute the stress generated by functional load, minimize the contraction stress and ensure a good bond between dentine and post, the composite cement should have a low conversion rate and, consequently, a low modulus of elasticity while maintaining a good mechanical resistance.

When a post restored tooth undergoes stress, the most rigid element of the tooth shifts the mechanical stress to the most flexible one; this may result in a root fracture or debonding of the post. For this reason, in order to obtain a homogenous tooth structure, the various restorative materials used should have a similar modulus of elasticity, which should also be approximately the same as dentine. It is therefore advisable to use cement with a low modulus of elasticity, which would not negatively affect the fracture resistance of the restored tooth.

The presence of voids or bubbles in the cement should also be taken into account. These faults reduce the modulus of elasticity and create a larger free contraction surface area thus contributing to reduce the contraction stress of the composite. However, due to their unpredictability, voids and bubbles cannot be considered an advantage. In addition, voids impede an appropriate cementation of the post, thus causing its debonding.

Since the presence of coronal dentine can increase retention to a considerable degree, the bond strength obtained using light-cure systems could guarantee good clinical success to restore teeth that retain a significant quantity of coronal tissue.

Conclusions

Currently, dual cured systems still represent the most reliable choice for post cementation. On the other hand, light cure systems may allow an improved apical seal as well as a more even distribution of the stress along the canal walls. Since light cure systems do not require mixing and can be cured at any time they undoubtedly represent a considerable advantage for clinicians.

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References