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Influence of luting agent translucency on fiber post retention

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The aim was to assess the influence of cement translucency on the retentive strength of luted fiber posts. Twenty extracted human premolars were randomly divided into four equal groups, based on the combinations of materials to be tested. Two post types of the same size, shape, and chemical composition, but different light-transmission properties [Translucent post (TP) and Opaque post (OP)] were selected. The two post types were luted using the etch-and-rinse, light-curing adhesive in combination with two shades of the same resin cement of markedly different light-transmitting ability [Transparent shade (TS) and Opaque shade (OS)]. Early post retention was assessed using the thin-slice push-out test. Post type did not significantly influence post retention; however, cement translucency emerged as a relevant factor in intraradicular cementation, with the TS achieving higher push-out strengths. The between-factor interaction was also statistically significant; specifically, OP-OS yielded significantly lower retentive strengths than all the other groups. Post translucency did not influence post retention, provided that a highly translucent cement was utilized for luting.

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Fiber-reinforced composite (FRC) posts are commonly used to restore endodontically treated teeth that show excessive loss of coronal tooth structure (1, 2). Resin-based luting agents, in combination with an appropriate adhesive system, are indicated for their cementation inside the root canal (3). However, achievement of strong and stable adhesion to radicular dentin is challenged by several factors. Of these factors, the presence of debris, pulp tissue remnants, residual irrigants, or medicaments over the post space walls (4); the irregular histology of deep radicular dentin (5); the extremely high endodontic C-factor (6–8); and the limited control of application steps in deeper parts of the root canal (4) are worthy of attention.

Limited penetration of light in the narrow post space preparation has been considered as another critical issue that affects the efficacy of adhesive systems and luting agents to bond posts to dentin. Translucent FRC posts were introduced with the intention to enable the transmission of light to the deepest parts of the root canal. Nevertheless, not all posts claimed to be translucent actually transmit light (9–11) and, among posts that do transmit light, the quantity of light transmitted differs significantly and lessens as the dowel space depth increases (9, 10).

With regard to resin cements, inadequate polymerization of light-activated resins was recorded at deeper levels of the post space (12). Therefore, the use of dual-cured resin cements was advised for post cementation (13–15). Light curing was recommended also with dual-curing cements because some did not achieve an adequate degree of conversion and satisfactory mechanical properties in the absence of light (16, 17).

Several studies have been conducted to investigate the influence of post translucency on cement curing (18), mechanical properties, quality of the interface with dentin (19), and post retentive strength (20–27). With regard to the influence of cement translucency on post retention, a highly translucent light-curing flowable composite, originally marketed for bulk-filling of posterior composite restorations, was found to provide satisfactory retentive strength when used to lute endodontic fiber posts. The translucency of the material was considered effective at enabling uniform polymerization throughout the post space length (28). Similarly, the translucent shade of a light-cured self-adhesive resin composite for direct restorations was reported to achieve a retentive strength comparable with that of a dual-cure etch-and-rinse resin cement, when utilized for fiber post luting (27). However, the specific contribution of cement translucency to post retention has not been systematically assessed in previous research. It therefore seemed of interest to conduct a study aimed at verifying to what extent the light-transmitting properties of the luting agent affect the retention of translucent and opaque posts. Post retention was assessed using the thin-slice push-out test. The null hypothesis tested was that translucent or opaque posts achieve similar intraradicular retention, regardless of the light-transmitting properties of the luting agent.

Material and methods

Measurements of light transmission

A pilot study was conducted to assess the amount of light transmitted through the posts, as well as the translucency of the cements.

Two types of fiber post – Fiberglass Post Translucent Conical and Fiberglass Post Conical (Bioloren, Saronno, Italy) – were selected for having the same size, shape, and chemical composition, but different light-transmission properties. The quantity of photons transmitted through the posts irradiated with a light-curing unit (L.E. Demetron 1, Light Guide Curved 11 mm 1020898; Kerr, Danbury, CT, USA; power output 700 mW cm^{-2}) was measured using a spectrophotometer (PSD1000; Ocean Optics, Dunedin, FL, USA), following the same methodology used by Goracci *et al.* (9) for the evaluation of post translucency. Digital photographs (D100; Nikon, Tokyo, Japan) of the posts irradiated with light from the curing unit were taken in complete darkness.

Two different shades of the same resin cement (Variolink II; Ivoclar Vivadent, Schaan, Liechtenstein) were selected for the study: shade *Transparent* base and *Transparent* catalyst; and shade *Opaque white* base and *Yellow* catalyst. As the catalyst is available in only two shades (*Transparent* and *Yellow*), the specific combinations of base and catalyst were made in order to obtain two cements with as different translucencies as possible. For evaluation of the cement translucency [contrast ratio (CR)], disks of 15 mm in diameter and 0.5 mm in thickness were made using a steel mold. After applying the material in a mold, a Mylar film was pressed over the material surface with a 1-mm-thick glass plate. Light curing was performed (L.E. Demetron 1) for 10 s over the glass plate and for another 50 s after the glass plate was removed. No finishing techniques were used. Specimens were stored at room temperature for 24 h to allow for post-cure. A spectrophotometer (PSD1000; Ocean Optics), equipped with an integrating sphere (ISP-REF; Ocean Optics) and a 10-mm opening, was used in conjunction with corresponding color measurement software (OOILab 1.0; Ocean Optics). D65 illuminant and 10° standard observer were selected. Measurements were conducted against white and black calibrated field tiles. The CR was calculated by comparing the reflectance of light, 'Y' (the ratio of the intensity of reflected light to that of the incident radiant flux), of specimens against black (Yb) and white (Yw) backgrounds, using the following equation: CR = Yb/Yw. Also, digital photographs of the specimens were taken to visualize the difference in cement translucency.

Specimen preparation

Twenty premolars with a single root and a single canal, extracted for orthodontic or periodontal reasons, were selected for use in the study. All donors of the teeth (age range: 16–53 yr) gave their written, informed consent for use of the extracted teeth for experimental purposes. One well-trained researcher prepared the specimens for use in the experiments. The external debris was removed with a hand scaler and the teeth were stored in 0.5% chloramine-T solution (Euclorina; Bracco, Milano, Italy), at 4°C, for no longer than 1 month until used. The crowns of all teeth were sectioned perpendicular to the long axis, 1 mm above the cemento–enamel junction (CEJ), using a water-cooled diamond disk (Isomet; Buehler, Lake Bluff, IL, USA). Root canals were instrumented at a working length of 1mm from the apex using ProTaper Universal nickel-titanium rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland), successively from size S1 to size F2 (apical diameter 0.25 mm; taper 0.08). During preparation, the root canals were rinsed with 2.5% sodium hypochlorite at each change of instrument. The endodontic treatment was completed by obturation of the canals with cold, laterally condensed gutta-percha (Roeko, Coltène, Whaledent, Langenau, Germany) and canal resin sealer (AH Plus; Dentsply DeTrey, Konstanz, Germany). The filled roots were sealed with glass-ionomer cement (Fuji II; GC, Tokyo, Japan), and stored in water for 48 h to allow the sealer to set. Post spaces were subsequently prepared, 10 mm in depth, using the drills of the fiber post system (Bioloren), according to the manufacturer's instructions. A 4-mm apical seal of gutta-percha was maintained.

The teeth were then randomly allocated to four groups of equal size ($n = 5$) that were defined based on post and cement type, as follows:

- Group I: Fiberglass Post Translucent Conical luted with Variolink II cement shade *Transparent* base and *Transparent* catalyst;
- Group II: Fiberglass Post Conical luted with Variolink II cement shade *Transparent* base and *Transparent* catalyst;
- Group III: Fiberglass Post Translucent Conical luted with Variolink II cement shade *Opaque white* base and *Yellow* catalyst; and
- Group IV: Fiberglass Post Conical luted with Variolink II cement shade *Opaque white* base and *Yellow* catalyst.

The etch-and-rinse adhesive, ExciTE F (Ivoclar Vivadent), was used in all groups before application of the cement. The materials were used according to the manufacturers' instructions. The chemical composition, batch numbers, and application modes of the materials are reported in Table 1. Light curing was performed using a conventional quartz–tungsten–halogen light (L.E. Demetron 1), following placement of the light tip on the coronal end of the post. In order to prevent the light from reaching the cement through the external surface of the root, the root was placed through a piece of black cardboard positioned close to the coronal level.

Push-out bond-strength test

The thin-slice push-out test was performed in order to assess the retentive strength of luted posts. Another researcher, blinded to the type of post and type of cement used, performed the test. The portion of each root that contained the post was sectioned into six, 1-mm-thick slices using the Isomet saw under water cooling. The first section was made at a distance of 1 mm from the CEJ. Sectioning resulted in 30 slices per group for push-out bond-strength evaluation. The apical surface of each root slice was marked in order for the loading force to be applied in the apical–coronal direction, to move the post toward the larger part of the slice. To account for the

Table 1

Composition, batch numbers, and application mode of the materials used in the study

Material, batch number	Type	Chemical composition	Application mode
Total Etch, S18448	Etching gel	37% wt. phosphoric acid, water, thickening agent, color pigments	Apply Total Etch for 15 s; rinse off after 15 s with water using an endodontic syringe; remove excess water with a gentle air blast; use paper points to remove residual moisture without desiccating the etched dentin surface
ExciTE F, R54347	Light-curing, fluoride-releasing, single-component total-etch adhesive	HEMA, dimethacrylates, phosphonic acid acrylate, highly dispersed silicon dioxide, initiators, and stabilizers in an alcohol solution	Apply activated ExciTE F adhesive to the post space with a proprietary microbrush for 10 s; gently air dry and then remove excess with paper points
Variolink II, shade *Transparent* base R60764 and catalyst R59556; shade *Opaque white* base R72564, *Yellow* catalyst R44201	Dual-curing, fluoride-releasing, resin cement	Bis-GMA, UDMA, TEGDMA, barium glass filler, ytterbium trifluoride, mixed oxides, Ba-Al-fluoro-silicate glass, catalysts, and stabilizers	Mix the base and the catalyst of Variolink II and apply the mixed material to the post; seat the post into the root canal and hold it in place using slight pressure; light cure for 60 s
Fiberglass Post Translucent Conical	Conical shape (ø 1–1.45)	Silanized glass fibers; resin matrix	–
Fiberglass Post Conical	Conical shape (ø 1–1.45)	Silanized glass fibers; resin matrix	–

Bis-GMA, bisphenyl A glycidyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; TEGDMA, triethyleneglycol dimethacrylate; UDMA, urethane dimethacrylate.

tapered design of the post, two different sizes of cylindrical plungers were used for testing (a diameter of 1 mm for the coronal slices and a diameter of 0.70 mm for the apical slices). The plunger was positioned so that it only contacted the post on loading, introducing shear stresses along the bonded interfaces. Compressive load was applied on the apical aspect of the slice via a universal testing machine (Triax Digital 50; Controls, Milan, Italy), operating at a crosshead speed of 0.5 mm min^{-1}. The loading was performed until failure occurred, as manifested by extrusion of the post segment from the root slice.

A digital caliper (Orteam, Milan, Italy), with 0.01 mm accuracy, was used to measure the thickness of each slice, as well as the coronal and apical diameters of the posts. The area of the bonded interface (A) was calculated using the formula: $A = \pi(R + r)[h^2 + (R - r)^2]^{1/2}$, where R represents the coronal post radius, r represents the apical post radius, and h is the thickness of the slice in millimeters. To express the bond strength in megapascals (MPa), the failure load recorded in newtons (N) was divided by the area of the bonded interface (A) in mm^2.

Statistical analysis

The mean push-out strength was calculated for each root, and the means among roots were compared within each experimental group, separately, using ANOVA. As this test did not reveal any significant difference among means ($P > 0.05$) in any of the four groups, the individual root slices were considered as independent measurements and statistical units. After checking for normality of data distribution (Kolmogorov–Smirnov test, $P > 0.05$) and homogeneity of group variances (Levene's test, $P > 0.05$), two-way ANOVA was applied with push-out bond strength as the dependent variable and type of post and cement as factors. Tukey's test was used for post-hoc comparisons, as needed. The level of significance was set at $P < 0.05$ in all tests, and calculations were performed using the SPSS 18.0 software (SPSS, Chicago, IL, USA).

Results

A remarkable difference in transmission of light was observed between the two post types at coronal, middle, and apical levels of the posts and at the post tips. Relatively high light transmittance was exhibited by Fiberglass Post Translucent Conical. The light intensity decreased from the coronal level to the apical level of the post and was the highest at the apical tip (the photon counts recorded at coronal, middle, and apical levels of the post, and at the tip of the post, were 540, 276, 229, and 3,196, respectively). By contrast, Fiberglass Post Conical appeared to be completely opaque, as no transmission of light was recorded (0 photon counts at coronal, middle, and apical levels of the post

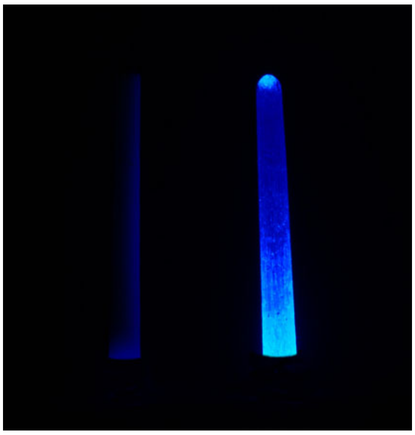

Fig. 1. Digital photograph of the posts irradiated with light from the curing unit taken in complete darkness (left, Fiberglass Post Conical; right, Fiberglass Post Translucent Conical).

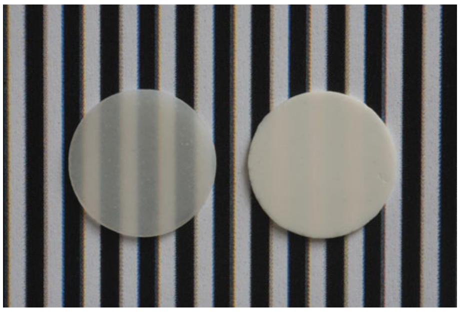

Fig. 2. Digital photograph of the cement disks, visualizing differences in their translucency (left, *Transparent* base and *Transparent* catalyst; right, *Opaque white* base and *Yellow* catalyst).

Table 2

Push-out bond-strength values

Post	Cement (Variolink II)*	
	Transparent shade (8.45 ± 2.68)	*Opaque white* shade (7.30 ± 2.32)
Fiberglass post translucent conical (8.25 ± 1.99)	8.28 ± 1.94[a]	8.22 ± 2.07[a]
Fiberglass post conical (7.50 ± 3.00)	8.62 ± 3.28[a]	6.37 ± 2.22[b]

Values are mean ± SD bond-strength values (MPa). Different superscript letters indicate statistically significant differences.
*Significant factor.

and at the post tip). Also, diverse values of translucency were recorded for *Transparent* (CR = 0.42) and *Opaque white* shades (CR = 0.91) of the cement. Digital photographs of the posts and cement disks are presented in Figs 1 and 2, respectively.

Table 2 reports the results of push-out bond strength testing. The type of fiber post did not significantly influence post retention ($P = 0.091$). Conversely, translucency of the cement was a significant factor ($P = 0.011$). The post–cement interaction was also statistically significant ($P = 0.015$). This led to post-hoc comparisons of all four groups using Tukey's test. The results of Tukey's test revealed that group where Fiberglass Post Conical posts were luted with *Opaque white* cement had significantly lower push-out strengths than did the other three groups ($P < 0.05$).

Discussion

In the present investigation, two posts, matched with respect to geometric characteristics, matrix composition, and type, diameter and orientation of the fibers, were employed. Geometric factors and chemical properties of the post types were therefore standardized so that any difference observed in post retention could be ascribed only to differences in transmission of light. Moreover, a wide variety of dual-cure cements are commercially available, and previous research has shown that the extent to which dual-cure resin cements are able to autopolymerize is highly product-specific (16). The intention to assess the influence of cement optical properties on post retention drove the choice of luting agent to be tested. Variolink II is indeed available in different shades and is a dual-cure cement that relies mainly on light activation for curing.

The selected shades differed substantially in light-transmitting properties. Translucency is usually determined in dentistry by the CR or Translucency Parameter (TP). The CR is the ratio of the reflectance of a specimen over a black backing relative to that over a white backing of a known reflectance, and is an estimate of opacity. It ranges from 0 to 1, with 1 equal to total opacity (29, 30). The two shade combinations of base and catalyst used in the present study showed a remarkable difference in terms of CR. The *Translucent* base/*Translucent* catalyst combination showed a CR of 0.41, similar to the CR value reported for human enamel, whereas for the *Opaque white* base/*Yellow* catalyst combination, a CR of 0.91 was measured, which was markedly more opaque than human dentin (which has a CR of around 0.65), and close to the values found for dental zirconia (31, 32).

The diversity in shade and translucency of resin cement was expected to affect the polymerization extent and the mechanical properties of the cured material (33, 34). In an earlier study, Reges *et al.* (35) reported significantly lower Knoop hardness values for the opaque shade of Variolink II in comparison with the other three shades tested.

Regarding the adhesive system, the light-curing bonding agent, ExciTE F, was selected to make curing within the post space exclusively light-dependent. Conversely, if the dual-cure formulation of the adhesive had been used (ExciTE DSC), the co-initiator of the self-cure reaction would have initiated cement polymerization, regardless of the amount of light transmitted (36).

Based on the finding of significant between-group differences in push-out bond strength, the null hypothesis had to be rejected. The results showed that the light-transmitting ability of the fiber posts did not affect their retention when the transparent shade of cement was used. It could therefore be assumed that even an opaque post can be effectively retained intraradicularly if a highly translucent composite resin is used for luting. Therefore, a substantial role for cement translucency in post retention emerges in the present investigation. Such a finding is in line with the outcome of previous studies, which reported satisfactory results when translucent shades of light-activated restorative flowable composites were tested for post retentive ability (27, 28). The evidence collected in the current study then suggests that the range of materials possibly available to the clinician for post luting can be extended to include light-activated composites, if provided in translucent shades. Among light-cured composites, the new flowable composites for bulk filling might be particularly promising, as their low-stress behavior and improved adaptation are desirable properties when luting within the confines of the post space. Bulk applicability would be advantageous also for a quick, one-step build-up of the core portion. Similarly, it would seem of interest to investigate the potential of a recently marketed sonic-activated translucent composite for bulk filling, when consecutively used for post cementation and abutment build-up (37–39).

As the results from the pilot study showed that the intensity of light transmitted through the translucent post decreased from the coronal (540 counts) to the apical (229 counts) level of the post, it might be interesting to verify whether cement curing was uniform throughout the entire length of the post space. Hence, in order to strengthen the evidence, the retentive strength of the post should be assessed with reference to the level of the root in future research.

Additionally, the finding of satisfactory post retentive strengths provided by the combination of a light-cure adhesive and a translucent light-cure cement allows the choice of bonding systems for post luting to be extended beyond the category of the dual-cure formulations. Simplified two-step and single-step adhesives could be utilized along with light-cure luting agents, without the concern for incompatibility phenomena that occur with self- and dual-cure cements.

Moreover, the finding of a significant role of cement translucency in post retention reduces the importance of light-transmitting properties of the post to a certain extent and gives the clinician more freedom to choose among the several types of post available. In this regard, the only limitation was to avoid the use of an opaque post along with an opaque cement as such a combination indeed resulted in significantly poorer post retention in the present study (Table 2).

It can be concluded that the translucency of the luting agent emerged as a relevant factor in intraradicular fiber post cementation. Post translucency did not influence post retention providing that a highly translucent cement was utilized for luting. However, a fiber post with limited light-transmission ability should not be used in combination with an opaque cement.

Conflicts of interest – The authors report no conflicts of interest.

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