C. Goracci*, G. Corciolani, A. Vichi, and M. Ferrari

Department of Dental Materials and Fixed Prosthodontics, University of Siena, Policlinico Le Scotte, Viale Bracci, Siena 53100, Italy; *corresponding author, cecilia.goracci@gmail.com

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Light-transmitting Ability of Marketed Fiber Posts

ABSTRACT

If proper polymerization of resin-based cements is to be achieved for fiber post luting, light activation is needed for photo-curing agents, recommended for self-curing materials. The study was aimed at verifying whether the light-transmitting ability of marketed fiber posts reflected the manufacturers' claims for translucency. Ten posts *per* type were light-irradiated with a curing unit. Spectrophotometric measurements of the amount of photons reaching different post levels were taken. Data were statistically analyzed (linear regression, two-way ANOVA; $\alpha = 0.05$). No light transmission was recorded through FibreKleer and Tech21 X-OP. For the other posts, light intensity decreased from coronal to apical and rose again at the apical tip, where it peaked for GC Fiber Post, Macrolock Illusion Post, and Radix Fiber Post. Light transmission was significantly higher at the coronal level. A statistically significant difference in translucency was found for Dentin Post X and FRC Postec Plus in comparison with Reforpost, FibreKleer, Tech21 X-OP, and Composipost.

KEY WORDS: fiber post, light transmission, spectrophotometer.

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INTRODUCTION

The use of fiber posts for the restoration of endodontically treated teeth is supported by reliable clinical evidence (Cagidiaco *et al.*, 2008).

Fiber posts are passively retained inside the root canals, and resin-based luting agents are the materials indicated for their retention (Goracci *et al.*, 2007).

To develop mechanical properties adequate for clinical function, resin cements must achieve proper polymerization (Faria e Silva *et al.*, 2007a). Evidence has been found that limited degree of conversion may affect relevant properties, such as hardness and fracture toughness (Roberts *et al.*, 2004).

While impairment of resin polymerization at increased depths has been reported (Yap, 2000; Sigemori *et al.*, 2005), the use of light-transmitting posts has been suggested to enhance resin cure at all root levels. Light activation is needed with photocured luting agents, but is also recommended with the use of some dual-cure cements that have been shown to reach inadequate degrees of conversion in the absence of light (Caughman *et al.*, 2001; Braga *et al.*, 2002; Kumbuloglu *et al.*, 2004).

The use of translucent posts was also prompted by the introduction of the so-called 'one-shot' technique, a simplified post-luting procedure involving simultaneous curing of the adhesive and the dual-cure cement with a single light exposure (Martelli, 2000; Grandini *et al.*, 2004).

Translucent fiber posts have been reported to increase the depth of cure of photo-activated resin composites (Roberts *et al.*, 2004; Yoldas and Alaçam, 2005). However, when evaluating the Knoop Hardness bottom/top cure ratio, Roberts *et al.* (2004) found that it did not achieve the 80% threshold value at depths beyond 3 mm, suggesting inadequate polymerization of the resin composite surrounding the post at the middle-apical levels of simulated root canals. Based on these findings, the authors speculated that previous studies on light-transmitting posts assessing other polymerization parameters "may have liberally overestimated some light-transmitting posts' ability to increase the depth of cure" (Roberts *et al.*, 2004).

A similar concern regarding the efficacy of polymerization at the apical level was raised in a study evaluating the ability of translucent fiber posts to increase the degree of conversion of a dual-cure resin cement (Faria e Silva *et al.*, 2007b). Investigators were concerned that monomers from incompletely polymerized resin cement and adhesive may leak through the apical root filling and damage the periodontal tissue as a result of inflammatory, cytotoxic, and mutagenic reactions (Faria e Silva *et al.*, 2007b).

Recently, Galhano *et al.* (2008) reported that, in the presence of a translucent post, cement microhardness was reduced at increasing root depths as a result of light attenuation, and minimal light reached the apical region.

As a matter of fact, the majority of laboratory tests discriminating differences in local conditions of bonding along the root canal point out that adhesion is less predictable at the apical third (Goracci *et al.*, 2007).

Several studies are available in the literature that assessed the influence of post translucency on the pull-out, thin-slice push-out, or microtensile bond strength of posts luted with adhesive cements used in different curing modes (Boschian Pest *et al.*, 2002; Giachetti *et al.*, 2004; Akgungor and

Akkayan, 2006; Kalkan *et al.*, 2006; Boff *et al.*, 2007; Mallmann *et al.*, 2007; Kececi *et al.*, 2008).

Also, the microtensile bond strength of a dual-cure core material to different regions of translucent fiber posts following several surface treatments has been evaluated (Aksornmuang *et al.*, 2006).

However, degree of conversion, hardness, and retentive strength of the resin composite surrounding the post are indicators of the efficacy of the induced polymerization, but they do not directly provide information on the amount of light transmitted by the post.

A great variety of fiber posts is currently marketed. In these fiber-reinforced composites (FRCs), fibers can be made of carbon, zirconia, quartz, glass, and zirconia-enriched glass. Posts are available in different geometries and sizes.

Factors such as the FRC composition (monomer type, filler type, their distribution) and the geometry of the specimen have an influence on the absorption and scattering of light, therefore affecting the amount of light delivered to various depths of the FRC (Chen *et al.*, 2005).

In a study by Teixeira *et al.* (2006), light transmittance through different fiber posts was measured with a spectrometer on the focal plane of a light microscope. However, in this test the light source was positioned on the bottom end of the post, and light measurements were taken only at the opposite end.

More recently, dos Santos Alves Morgan *et al.* (2008) compared the luminous conduction of several posts by measuring the transmitted light as a function of the post cross-sectional area at the coronal, middle, and apical thirds. However, the authors recognized that measuring the amount of energy transversely may have been a limitation of the study. It is rather the ability of the post to transmit the light radially that is critical for cement polymerization.

Based on these premises, it seemed of interest to verify the light-transmitting ability of various commercially available fiber posts by taking spectrophotometric measurements radially at different post levels, as well as at the apical tip.

The working hypothesis was that even through posts claimed to be translucent, a minimal amount of light may be transmitted radially to reach the surrounding cement layer, particularly at the apical level.

Table 1. Manufacturers and Characteristics of the Posts Investigated

Post	Fibers	Resin Matrix	Shape
RelyX Fiber Post 3M ESPE, St.Paul, MN, USA Size 1	Glass	Resin	Double-tapered
FRC Postec Plus Ivoclar-Vivadent, Schaan, Liechtenstein Size 1	Glass	UDMA, TEGDMA, Ytterbium trifluoride, highly dispersed silicon dioxide	Tapered
GC Fiber Post Tokyo, Japan Size 1,2	Glass	Methacrylate	Double-tapered
DT Light Post Illusion RTD, Grenoble, France Size 1	Quartz	Epoxy	Double-tapered
DT Light Post RTD Grenoble, France Size 1	Quartz	Epoxy	Double-tapered
Macrolock Illusion Post RTD, Grenoble, France Size 1	Quartz	Epoxy	Tapered, circumferential head grooves, spiral head serrations
Radix Fiber Post Dentsply Maillefer, Ballaigues, Switzerland Size 1	Zirconium enriched glass	Epoxy	Double-tapered
DT Light Safety Lock VDW, Munich, Germany Size 1	Pre-conditioned quartz	Epoxy	Double-tapered
Dentin Post X Komet, Lemgo, Germany Size 444L12.070	Glass	Epoxy	Tapered with a retentive head
Snowpost Abrasive Technology, Lewis Center, Ohio, USA Size 1	Zirconia-rich glass	Epoxy	Cylindrical with long apical cone
Reforpost Angelus, Londrina, PR, Brasil Size 1	Glass	Bis-GMA	Serrated
FibreKleer Serrated Post Jeneric/Pentron, Wallingford, CT, USA Size 1.125	Glass	Bis-GMA, UDMA, HDDMA	Serrated
Tech21 X-OP Carbotech for Isasan, Rovello Porro, Italy Size 12	Silica-zirconium	dppMor (diphenilpropane, metiloxirane)	Tapered
Composipost RTD, Grenoble, France Size 1	Carbon	Epoxy	Two-stage parallel

MATERIALS & METHODS

Fourteen types of fiber posts available in the market were investigated. The posts exhibited different shapes, diameters, and conicities. To standardize the geometric properties as much as possible, we selected the post sizes that were most similar among the different brands (Table 1). Also, to standardize the length, we cut each post at 15 mm from the tip using a diamond bur (FG 4205 L, Intensiv, Grancia, Switzerland) mounted on a high-speed handpiece (Super-Torque Lux 3 650B, KaVo Dental, Biberach/Riss, Germany) under water spray.

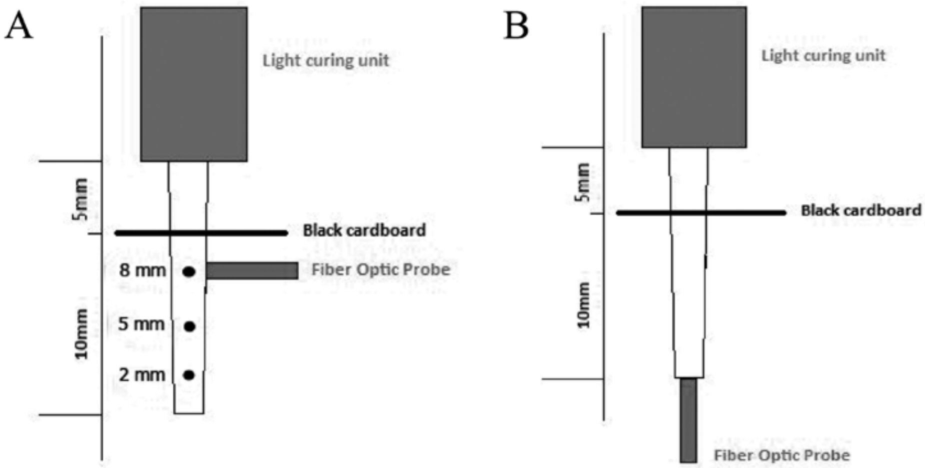

Figure 1. A schematic of the experimental set-up for spectrophotometric measurements. For selective detection of the light transmitted through the post, each post was placed through a piece of black cardboard taken from the Q-14 color separation scale (Kodak Co., Rochester, NY, USA). The distance between the card and the apical tip of each post was set at 10 mm, and the light-curing unit was placed on the opposite end of the post, so that the distance from the card was 5 mm. The light-curing unit/post system was positioned on a stand. The post was placed perpendicular to the black cardboard, and the optical fiber was oriented perpendicular to the post and thus stabilized. **(A)** Recordings at the coronal, middle, and apical levels of the post. **(B)** Recording at the post's apical tip.

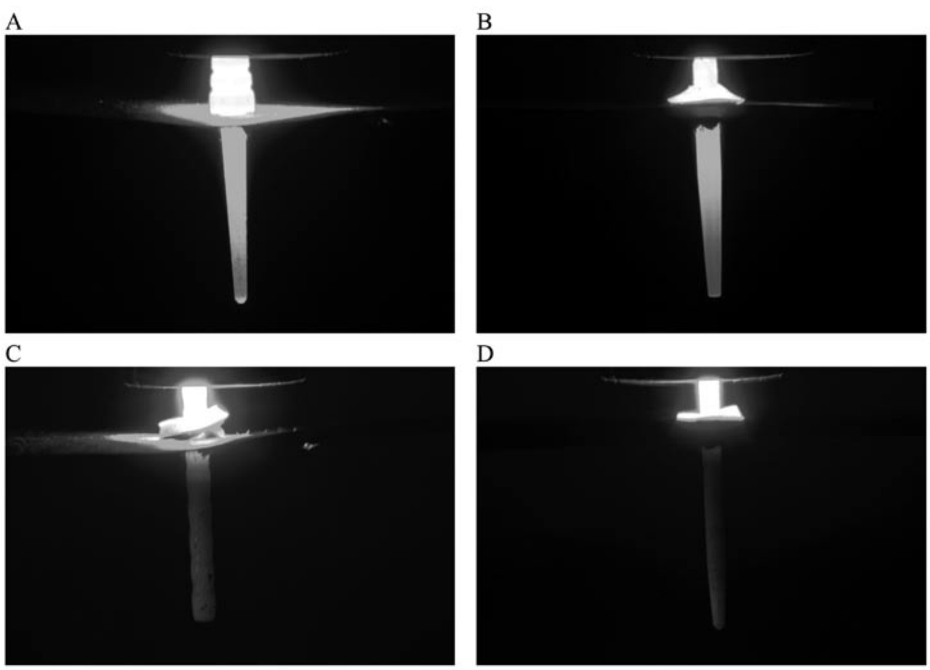

Figure 2. Digital photographs of the posts light-irradiated from the curing unit. Photographs were taken in a completely dark environment. The set-up was the same as for spectrophotometric measurements, allowing only the light transmitted through the post to show in the photograph beyond the black cardboard. **(A)** Dentin Post X, Komet; **(B)** FRC Postec Plus, Ivoclar-Vivadent; **(C)** FibreKleer Serrated Post, Jeneric/Pentron; and **(D)** Tech21 X-OP, Carbotech-Isasan.

The quantity of photons transmitted through posts irradiated with a light-curing unit (L.E.Demetron 1, Light Guide Curved 11mm 1020898, Kerr, Danbury, CT, USA) was measured with a spectrophotometer (PSD1000, Ocean Optics, Dunedin, FL, USA). Measurements were taken with a 50-μm fiber optic (P50-2-UV-VIS, Ocean Optics), that was placed at three different levels along the post (2 mm, 5 mm, 8 mm), as well as at the tip of the post. These distances were always verified by an electronic digital caliper with a 10-μm resolution (1651 DGT, Beta, Milan, Italy). The experimental set-up for spectrophotometric measurements is illustrated in Fig. 1.

The spectrophotometer was connected to a computer running spectrum analyzer software (OOIBase 32, Ocean Optics). The software was set in "scope" mode, for evaluation of the light counts that correlated to the quantity of photons received from the CCD detector of the spectrophotometer. At 470 nm, for each count, 30 photons were received from the detector of the instrument. Counts were recorded in complete darkness for 10 posts of each type. Every 10 measured posts, we used radiometry (Optilux Radiometer, sds/Kerr, Orange, CA, USA) to ascertain that the output of the light tip remained over 700 mW/cm^2. Additionally, photographs of the posts light-irradiated from the curing unit were taken in complete darkness (D100, Nikon Corporation, Tokyo, Japan) (Fig. 2).

Statistical Analysis

A linear regression analysis was applied to data from the coronal, middle, and apical levels, with 'counts' as the dependent variable, and 'post type' and 'post level' as predictors. Also, having checked that data passed the normality and equal variance tests, we applied the two-way Analysis of Variance with 'counts' as the dependent variable, and 'post type' and 'post level' as factors. The Tukey test was used for *post hoc* comparisons.

Furthermore, differences in light transmission among the posts at all levels were statistically assessed (one-way Analysis of Variance, Tukey test). In all analyses, the level of significance was set at $\alpha = 0.05$.

RESULTS

Light transmission was precluded through FibreKleer (Fig. 2c), Tech21 X-OP (Fig. 2d), and Composipost, and limited to the coronal level for Reforpost (Table 2).

For the other posts, light intensity decreased from coronal to apical and rose again at the apical tip. For GC Fiber Post, Macrolock Illusion Post, and Radix Fiber Post, light intensity peaked at the apical tip (Table 2).

The linear regression model showed that post type and post level had a significant influence on light transmission ($p < 0.001$). Also, according to the two-way ANOVA, post type and post level were significant factors for light transmission ($p < 0.001$).

In particular, the Tukey test showed that light transmission was significantly higher at coronal than at middle and apical levels ($p < 0.05$). At the latter two levels, the conditions of light transmission were comparable ($p > 0.05$). With regard to post type, the difference in translucency was found to be statistically significant for Dentin Post X and FRC Postec Plus in comparison with Reforpost, FibreKleer, Tech21 X-OP, and Composipost.

Statistically significant differences in the light-transmitting ability exhibited by the posts at the assessed levels are shown in Table 2.

Table 2. Means and Standard Deviation Values of Counts Recorded at Different Post Levels for Each Post Type (N = 10) (significant differences in counts among the post types highlighted by different letters)

Level	Post	Mean	SD	p < 0.05
CORONAL	Dentin Post X	1459	19.1	A
	FRC Postec Plus	1284	33	B
	DT Light Post Illusion	1044	27.5	C
	DT Light Post	891	14.5	D
	DT Light SL	882	16.8	D
	RelyX Fiber Post	816	25	E
	GC	815	14.3	E
	Radix Fiber Post	604	24.1	F
	Macrolock Illusion	412	22	G
	Snowpost	294	16.4	H
	Reforpost	106	14.3	I
	FibreKleer/Tech21 X-OP/ Composipost	0	0	L
MIDDLE	Dentin Post X	579	17.9	A
	FRC Postec Plus	561	17.3	A
	DT Light Post Illusion	471	25.1	B
	Radix Fiber Post	394	18.3	C
	DT Light Post	386	14.3	C
	DT Light SL	380	16.3	C
	GC	376	20.1	C
	Macrolock Illusion	296	19.5	D
	RelyX Fiber Post	211	31.4	E
	Snowpost	186	15.7	E
	Reforpost/FibreKleer/Tech21 X-OP/ Composipost	0	0	F
APICAL	Radix Fiber Post	390	14.1	A
	Dentin Post X	297	18.3	B
	FRC Postec Plus	276	15	B
	GC	229	19.1	C
	Macrolock Illusion	210	18.2	CD
	DT Light Post	203	14.2	D
	DT Light SL	197	16.3	D
	DT Light Post Illusion	115	13.5	EF
	RelyX Fiber Post	110	17	EF
	Snowpost	98	13.1	F
	Reforpost/FibreKleer/Tech21 X-OP/ Composipost	0	0	G
TIP	Radix Fiber Post/Macrolock Illusion/GC	4096	0	A
	Dentin Post X	2296	25	B
	DT Light Post	1684	24.6	C
	DT Light SL	1673	24.5	C
	FRC Postec Plus	1639	29.2	C
	DT Light Post Illusion	817	15.6	D
	RelyX Fiber Post	193	18.3	E
	Snowpost	140	14.1	F
	Reforpost/FibreKleer/Tech21 X-OP/ Composipost	0	0	G

DISCUSSION

FibreKleer, Tech21 X-OP, and Composipost appeared to be completely opaque, whereas with Reforpost light passage was limited to the coronal portion. Such findings were expected for the carbon fiber Composipost. However, Reforpost and FibreKleer contain glass fibers and a methacrylate-based resin matrix.

Particularly for FibreKleer, a specific claim of translucency is made by the manufacturer. Slightly more than 30% of the incident 470-nm-wavelength light has been recorded at the apical tip of FibreKleer posts (Teixeira *et al.*, 2006). However, in this study, the 'parallel' shape was tested, whereas in the present investigation the 'serrated' design was examined. The question can therefore be raised whether the serrations throughout the post length may affect light transmission unfavorably.

With regard to Reforpost, this study's data are in line with the findings of dos Santos Alves Morgan *et al.* (2008), whose cross-sectional measurements recorded low luminous energy at the coronal third, and null light transmission at the middle and apical levels.

Consequently, with the glass fiber posts Reforpost and FibreKleer Serrated, the use of light-cured luting agents should be contraindicated, and the use of dual-cure cements mainly dependent on light activation for polymerization should be considered with caution.

In Tech21 X-OP, opacity may be ascribed to the presence of silica-zirconium fibers.

Also, for Snowpost, a reduced passage of light was noticed at all levels. However, no claim of post translucency is made for this post, which features zirconia-rich glass fibers in an epoxy resin matrix.

The highest overall translucency was exhibited by Dentin Post X and FRC Postec Plus, both glass fiber posts with a tapered shape.

With regard to DT Light SL, it should be noted that the industrial pre-coating of the post surface with silicate/silane layers for enhanced adhesion of core and luting materials (Mazzitelli *et al.*, 2008) did not interfere with light transmission.

For DT Light Post Illusion, light transmittance was relatively high at coronal and middle levels, but dropped quite remarkably at the apical level.

Statistical analysis highlighted that, regardless of the type of post, the apical portion was reached by a significantly lower amount of light.

This finding, in agreement with previous reports (dos Santos Alves Morgan *et al.*, 2008; Galhano *et al.*, 2008), supports the concern that light intensity at the deepest level of the root canal may be insufficient to induce proper polymerization of the adhesive cement. Such a limitation would definitely affect the properties of light-cured composites, but could also influence the outcome of dual-cure cements relying mainly on light activation for curing.

It would be of interest to complement the spectrophotometric measurements with Fourier Transform Infra-red or Raman spectroscopy and with push-out testing, to assess the extent to which a drop in light irradiation affects the degree of cure and retentive ability of the adhesive cement.

It should also be considered that, in addition to the potential for periodontal tissue damage, poorly polymerized monomers may undergo degradation phenomena possibly affecting bond durability (Faria e Silva *et al.*, 2007b).

The optical behavior of the glass fiber when the FRC is light-irradiated can be assimilated to that of a multimode fiber optic. In a multimode fiber, light beams are guided along the fiber core by total internal reflection. Light rays that, inside the core, cross the cladding boundary with an angle greater than the critical angle for the boundary itself are completely reflected. The critical angle is determined by the difference in refraction indices between the core and the cladding materials. Rays that meet the boundary at an angle lower than the critical angle are refracted from the core into the cladding, and do not convey light along the fiber. In the FRC post, the fiber acts like a core, the matrix like a cladding. This may possibly explain the differences in the optical properties emergent among the various post types in this investigation. The variability in diameter, fiber orientation pattern, and matrix generates different values of refraction index between fiber (core) and matrix (cladding), and therefore different conditions for light transmission along the post. In relation to light wavelength, post sizes and shapes, and diameters of the reinforcing fibers, differences in the amount of recorded light counts may result among the various post types. This may also explain the peak in light counts measured at the apical tip for several posts. Since the reinforcing fibers have a unidirectional longitudinal orientation, light beams may effectively be carried along the fibers up to the tip.

It should therefore be of interest in future research to specifically assess the influence of post geometric characteristics on light transmittance.

Spectrophotometric measurements were taken in complete darkness, to avoid any possible interference of environmental light.

In conclusion, spectrophotometric measurements led to rejection of the null hypothesis, since significant differences in light transmittance were found among the posts.

In light-transmitting posts, a significant drop in the amount of light reaching the apical portion was reported that may have a bearing on the curing efficacy of resin composites in the depth of the root canal.

For this reason, the optical behavior of posts should be taken into due consideration when the material for luting is chosen.

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