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Abstract

Purpose: The aim of this study was to investigate how well core build-up composite polymerizes when light is transmitted through a fiber post.

Materials and Methods: Two different composites were studied: light-cure flowable short fiber-reinforced composite (SFRC) everX Flow (GC) and dual-cure composite Gradia Core (GC). Three different fiber-reinforced composite (FRC) posts were used. Two of them were prefabricated FRC posts, MI Core Fiber Post (GC) and Snowpost (Abrasive Technology), with a cross-linked polymer matrix. The third was individually formed FRC post with semi-interpenetrating polymer network (semi-IPN) polymer matrix, everStick Post (GC). A 4 mm thick polyvinylsiloxane putty disc was prepared with a 1.5 mm diameter hole to hold the post in place during curing. A light-protected cylinder was filled with composite and the putty disc with the post was placed on the cylinder. Light was transmitted to cure the composite through the post for 20 or 40 s. Immediately after light-curing, the posts were gently scraped clean of non-polymerized composite and wiped with ethyl alcohol. The posts with the attached, solidified composite, were then weighed and visually analyzed for determining quantity of polymerized composite on post surface. In addition, the diameters of the posts were measured at six different depths (4, 8, 12, 16, 20, and 24 mm) from the cervical end.

Results: The composites everX Flow (GC) and Gradia Core (GC) did not differ statistically when looking at the quantity of attached composite to different posts (ANOVA, $p > 0.1$). The MI Core Fiber Post group and everStick Post (GC) group showed significantly higher quantity of attached composite on post surface compared to the Snowpost group ($p < 0.001$), suggesting better transmission and scattering of curing light.

Conclusion: The results showed that composite resins may be adequately polymerized by curing light through the post only. This suggests that, in some occasions, light-curing composites could be used for luting fiber posts to the root canal.

Key words: Flowable short fiber-reinforced composite, Fiber-reinforced composite post, Individually formed fiber-reinforced composite post.

Introduction

Fiber-reinforced composite (FRC) posts are widely used in severely damaged endodontically treated teeth. Over the years, various post materials have been introduced, but nowadays glass fiber-reinforced composite posts (FRC) have gained popularity in restorative dentistry due to their favorable mechanical properties and potential for adhesive bonding[1-3].

Fiber posts can be classified into two main categories: prefabricated and individually formed posts. Prefabricated posts consist of a cross-linked polymer matrix around the fibers, whereas individually formed posts are composed of unidirectional longitudinal fibers surrounded by a semi-interpenetrating polymer network (semi-IPN) polymer matrix. The semi-IPN polymer matrix of individually formed posts contains of linear polymers that can be dissolved by the monomers of the adhesive[4]. Thereby the bondability of the individually formed FRC post is improved compared to prefabricated FRC post, which has a fully polymerized and cross-linked polymer matrix and therefore relies primarily on mechanical retention for adhesion in the root canal.[5]

Bonding to root canal dentine is particularly challenging due to the influence of multiple factors[1,6,7]. Achieving durable bonding is essential for the long-term success of the post restoration. Poor bond strength can result in post debonding, which is the most common complication associated with prefabricated fiber posts[1,8,9]. Due to the difficulty of light penetration into the root canal, post cementation is typically performed using dual-cure resin cements[1]. The light-transmitting ability of fiber posts differ greatly depending on their composition and structure[1]. Laboratory research has shown that individually formed FRC posts demonstrate superior translucency, which facilitates improved light transmission into the root canal and enables more effective polymerization of the surrounding resin cement[10,11]. In selected cases, high translucency of fiber post may theoretically enable the use of light-cured resin composite for post cementation.

Over the past few years, the use of short fiber-reinforced composite (SFRC) has seen a notable rise. Unlike traditional composite resins that incorporate particulate fillers, SFRC utilizes randomly oriented short E-glass fibers within the resin matrix. This fiber reinforcement significantly enhances important mechanical properties such as fracture toughness, flexural strength, and load-bearing capacity[12-14]. According to the literature, laboratory studies have shown promising results when using flowable SFRC, such as everX Flow (GC), not only as a base layer under conventional composite fillings, but also as core material in combination with individually formed glass FRC posts[15]. In a recent laboratory study, bond strength was measured with a Push-out test on individually formed FRC posts cemented with light-cure SFRC (everX flow) in dentin discs[16]. The results were promising, indicating improved interfacial adhesion between post and dentin[16]. Additional research is still needed to gain a better understanding of the behavior and durability of light-cure short fiber-reinforced composite in fiber post cementation.

The aim of this *in vitro* study was to investigate how well light-cure flowable short fiber-reinforced composite (SFRC) polymerizes compared to dual-cure composite, when light is transmitted through different FRC posts. The hypothesis was that both composites may be polymerized by light transmitted through the post. In addition, the cement orientation at different depths of the FRC posts was evaluated.

Materials and Methods

In this study, two different composite resin cements were compared, light-cure flowable short fiber-reinforced composite (SFRC) everX Flow (Bulk Shade, GC, Japan) and dual-cure composite Gradia Core (GC, Japan). Gradia Core is commonly used for post cementing, while everX Flow is a flowable SFRC designed to replace dentine and reinforce composite restorations (Table 1).

Table 1. The tested composite materials used as luting cement.

Material	Type of material	Lot	Composition
everX Flow (GC)	Light-cure flowable short fiber-reinforced composite	2201271 2212101 2303071 2302171 2407261 2206031	Silanated short e-glass fibers (ø 6µm and length 100µm) and barium glass fillers (0.7µm), bis-EMA, TEGDMA and UDMA
Gradia Core (GC)	Dual-cure composite	2212121 2402141	Methacrylic acid ester, fluoro-alumino-silicate glass, silicon dioxide

Three different fiber-reinforced composite (FRC) posts were used: Two of them were prefabricated FRC posts, MI Core Fiber Post (GC, Japan) and Snowpost (Abrasive Technology, United States), with a cross-linked polymer matrix. The third was individually formed FRC post with semi-interpenetrating polymer network (semi-IPN) polymer matrix, everStick Post (GC, Japan) (Table 2).

Table 2. The tested FRC posts.

Material	Type of FRC post	Polymer matrix	Composition	Post diameter (mm)	Post length	Lot
everStick Post (GC)	Individually formed	Semi-IPN	E-glass (electric glass, silanated), bis-GMA, PMMA	1.5	21.6 mm*¹	2404221
MI Core Fiber Post (GC)	Prefabricated	Cross-linked	AR-glass fibers, UDMA	1.6	22,1 mm	A-30577
Snowpost (Abrasive technology)	Prefabricated	Cross-linked	Zircon-rich glass fiber	1.6	18,6 mm	C811004

*¹ The everStick Posts lengths varied from 21.2 to 22.1 mm, with an average length of 21.6 mm.

The FRC posts were divided into three groups based on the manufacturer. Each post brand included a total of 20 posts. Each post group was further divided into two subgroups: one subgroup was cemented using everX Flow and the other using Gradia Core. Within each composite group, half of the samples (n=5) were tested with a light-curing time of 20 seconds, and the other half (n=5) with a curing time of 40 seconds.

To create the experimental setup, a plastic cylinder was cut from a syringe (height 24.5 mm) and covered with black tape to prevent light passing through. For the attachment of the post, a 4 mm thick polyvinylsiloxane (Lab-Putty, Coltene, Altstätten, Switzerland) disc with a 1.5 mm diameter hole was made. Since the hole in the putty wears out in use, a new putty was used for each test group to prevent light leaking through the putty (Figure 1).

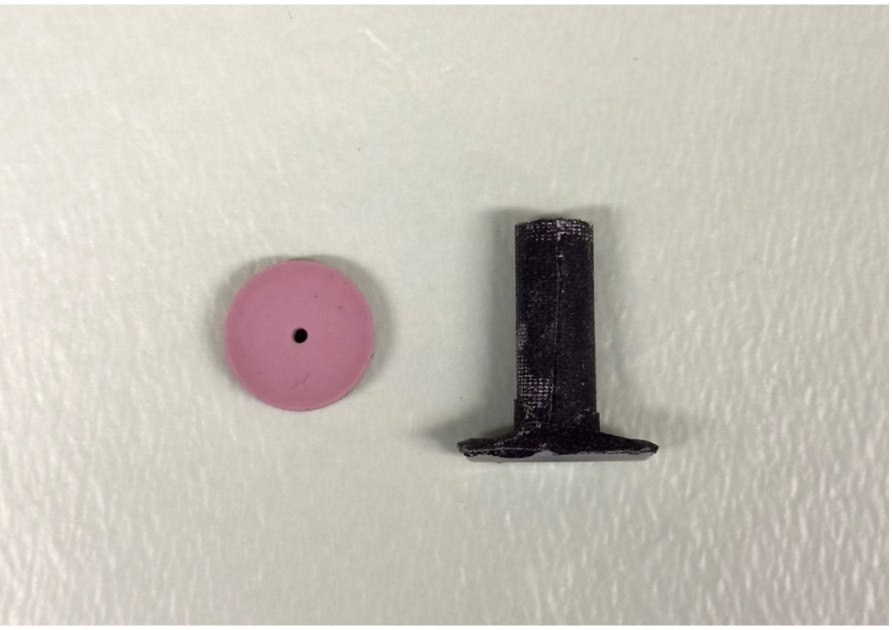

Figure 1. The 4 mm thick putty disc and the light-protected cylinder.

The FRC posts were pretreated according to manufacturers instructions. Additionally, the painted surface of the Snowpost at the cervical end was removed using sandpaper to allow light to pass into the post matrix. Snowpost and MI Core Fiber Post were rubbed with alcohol, then dried and treated with Ceramic Primer II (GC, Japan). The everStick Post was preshaped and individually formed into the form of a post by rolling it between two microscope glasses (Figure 2). After rolling, posts were light-cured for 40 seconds from three different points. The surface of everStick Post was then treated with Modeling liquid (GC, Japan) for 3 minutes, dried and light-cured for 10 seconds.

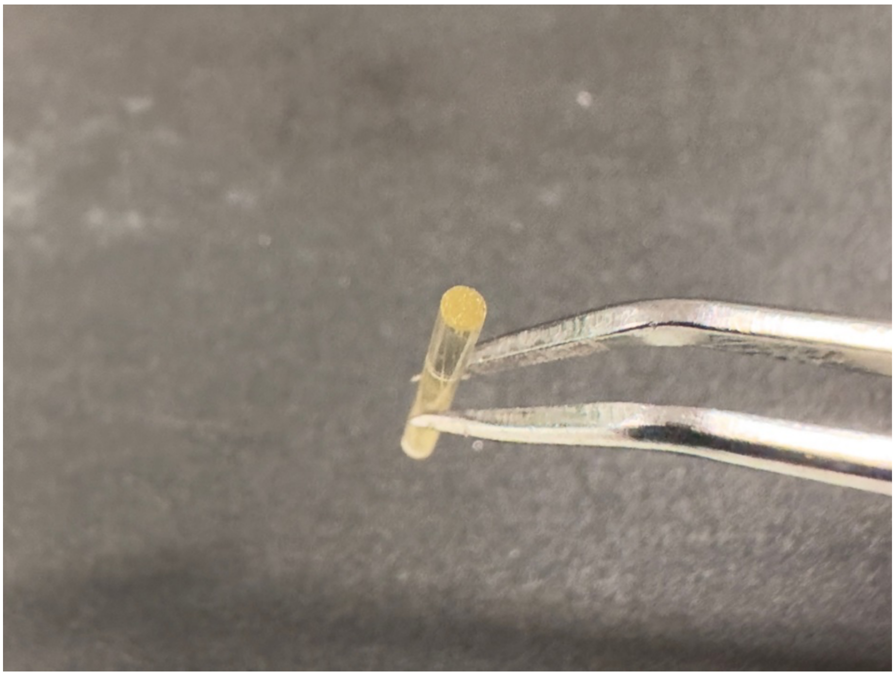

Figure 2. Preshaped and individually formed everStick Post.

FRC posts were then attached through the hole into the putty disc. In the test setup, the light-protected cylinder was completely filled with either one of the two composites, Gradia Core or everX flow, and the putty disc with the post was placed on top of the cylinder, with the post submerged into the composite. Light-curing (20 or 40 sec) was performed with Elipar S10 (3M ESPE, Maplewood, USA) from the top of the putty disc with the post, allowing light transmission to the composite only through the FRC post (Figure 3 and 4).

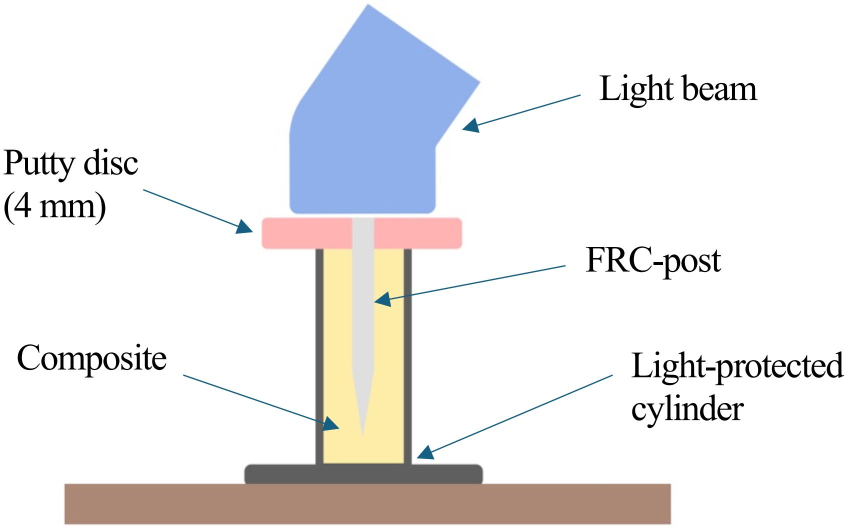

Figure 3. An illustrative drawing of the test setup.

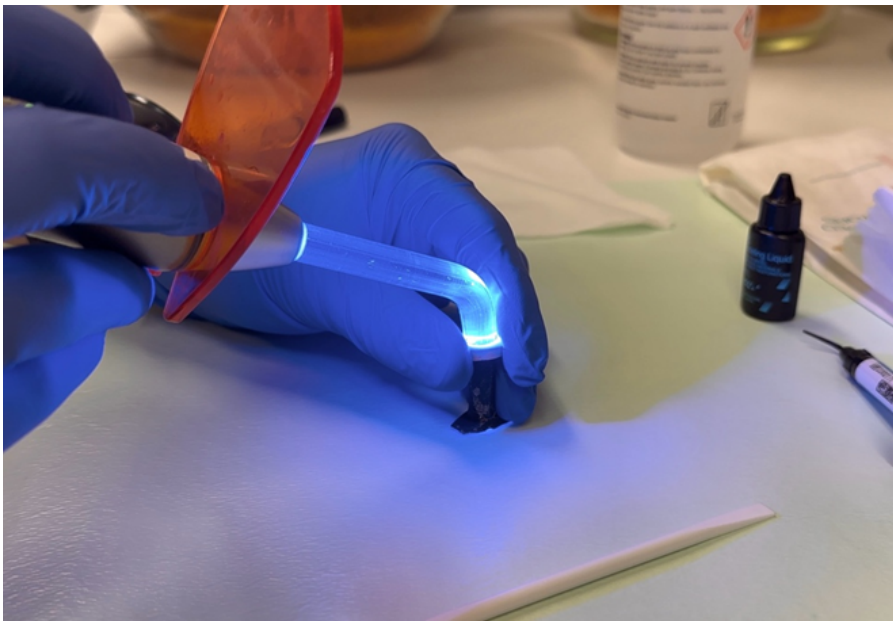

Figure 4. The specimen undergoing light polymerization.

After light-curing, the posts were immediately removed from the cylinder and gently scraped clean of non-polymerized composite using a plastic spatula (Figure 5). Additionally, the posts were wiped with ethyl alcohol to ensure that all non-polymerized residual composite was removed. Then the FRC posts were weighed with XS 105 Dual range (Mettler Toledo, Columbus, USA) and the mass of the attached composite was calculated. To examine the distribution of the composite, the diameter of the attached composite around the post was measured at 4 mm intervals. Measuring points were: 4 mm, 8 mm, 12 mm, 16 mm, 20 mm and 24 mm starting from the cervical end. At each interval, the diameter was measured with an electronic caliper at the thickest and thinnest points to calculate the average thickness of the composite around the post. Additionally, each post was photographed to observe the orientation of the composite around the post.

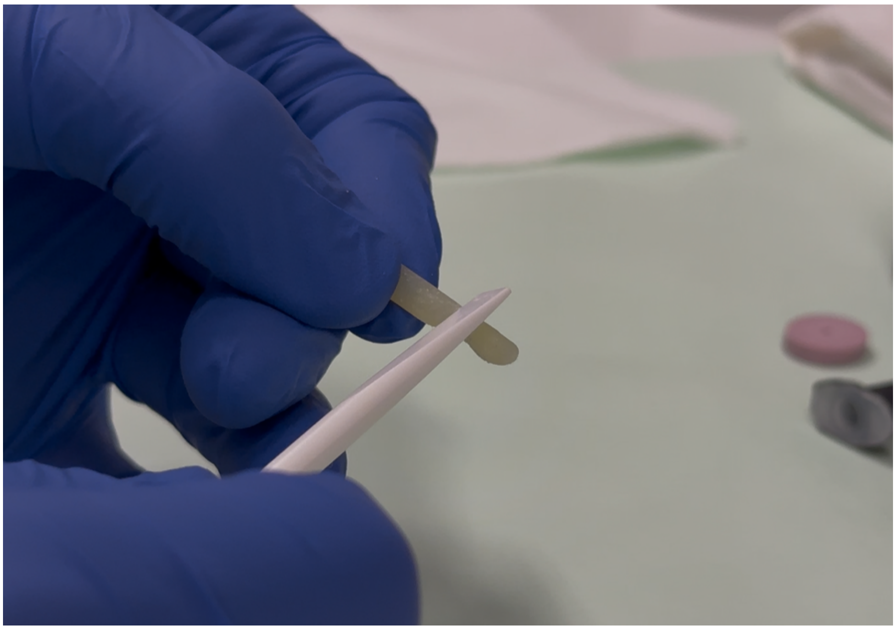

Figure 5. Scraping of non-polymerized composite around the post after light-curing.

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 23 (IBM, Armonk, New York, USA). Data were analyzed using two-way ANOVA with independent factors (post, diameter), followed by Tukey's Post Hoc test. The level of statistical significance was considered to be 0.05.

Results

Both the MI Core Fiber Post and everStick Post groups showed significantly higher amount of attached composite on the post surface, as well as larger composite diameters at various depths from the cervical end, compared to the Snowpost group, where no composite was attached ($p < 0.001$). This was observed with both everX Flow and Gradia Core composites (Figure 6, 7a, 7b, 8a, 8b and Table 2).

In addition, within the MI Core Fiber Post and everStick Post groups, a 40-second light-curing time resulted in significantly higher amount of attached composite to post surface compared to the 20-second curing time (ANOVA, $p < 0.001$) (Figure 7a and 7b).

The composites everX Flow and Gradia Core did not differ significantly in the amount of attached composite (g) on the post groups (ANOVA, $p > 0.1$) (Figure 7a and 7b).

Visual inspection of the post groups supported the results. Larger amount of composite on the post surfaces was visually observed in the 40-second light-curing groups compared to the 20-second groups. Furthermore, visible composite adhesion was observed on the MI Core Fiber Post and everStick Post surfaces, while no composite was seen on the Snowpost surfaces (Figure 6).

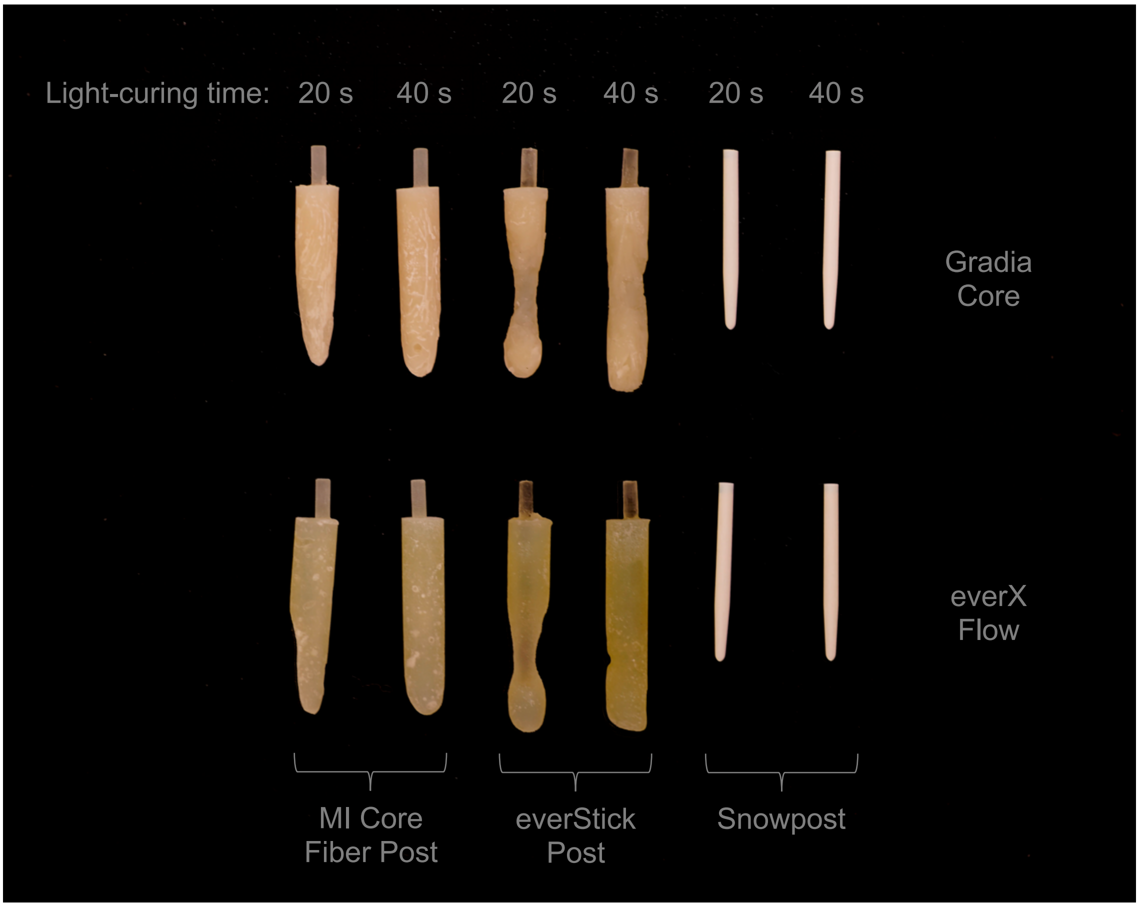

Figure 6. A photograph illustrating a typical example of the orientation of polymerized solid composite on the tested FRC posts and composites.

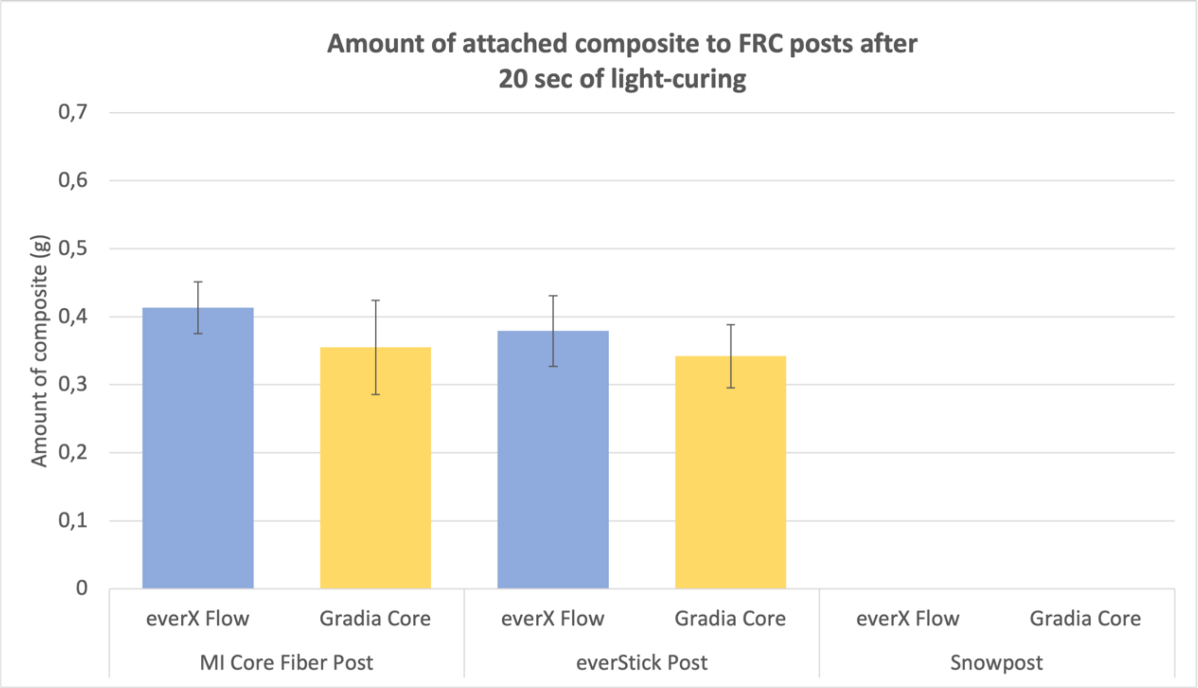

Figure 7a. The average amount of polymerized composite (g) attached to different FRC posts after 20 seconds of light curing and scraping. Vertical lines represent standard deviation.

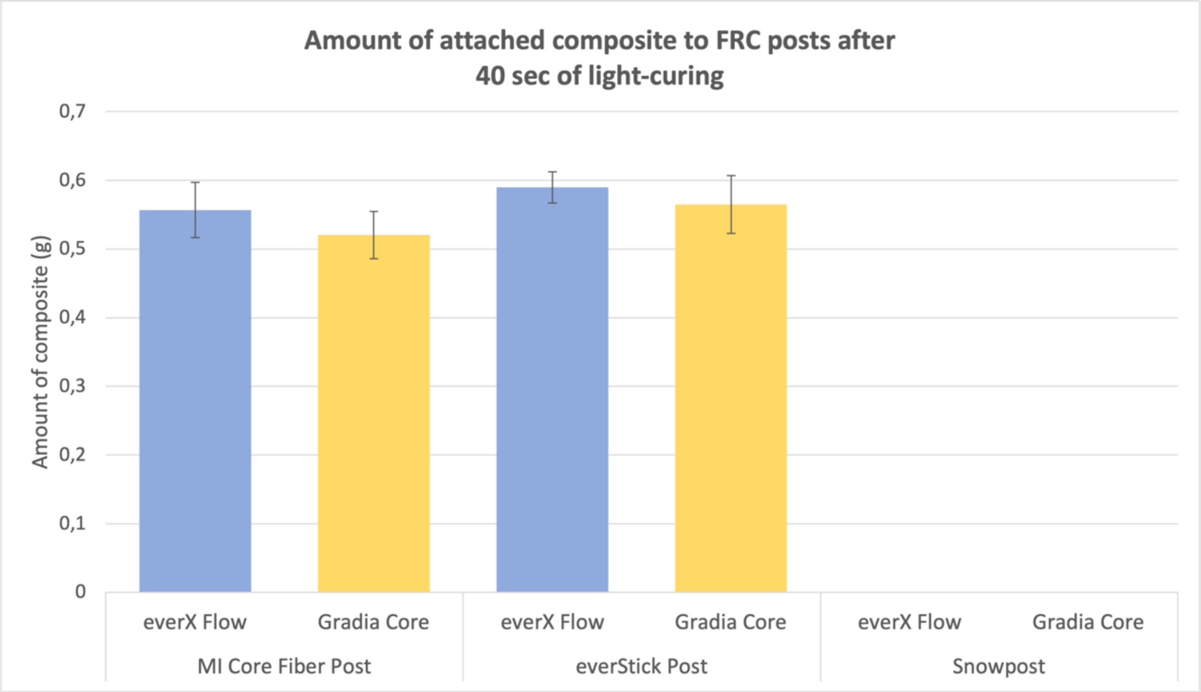

Figure 7b. The average amount of polymerized composite (g) attached to different FRC posts after 40 seconds of light curing and scraping. Vertical lines represent standard deviation.

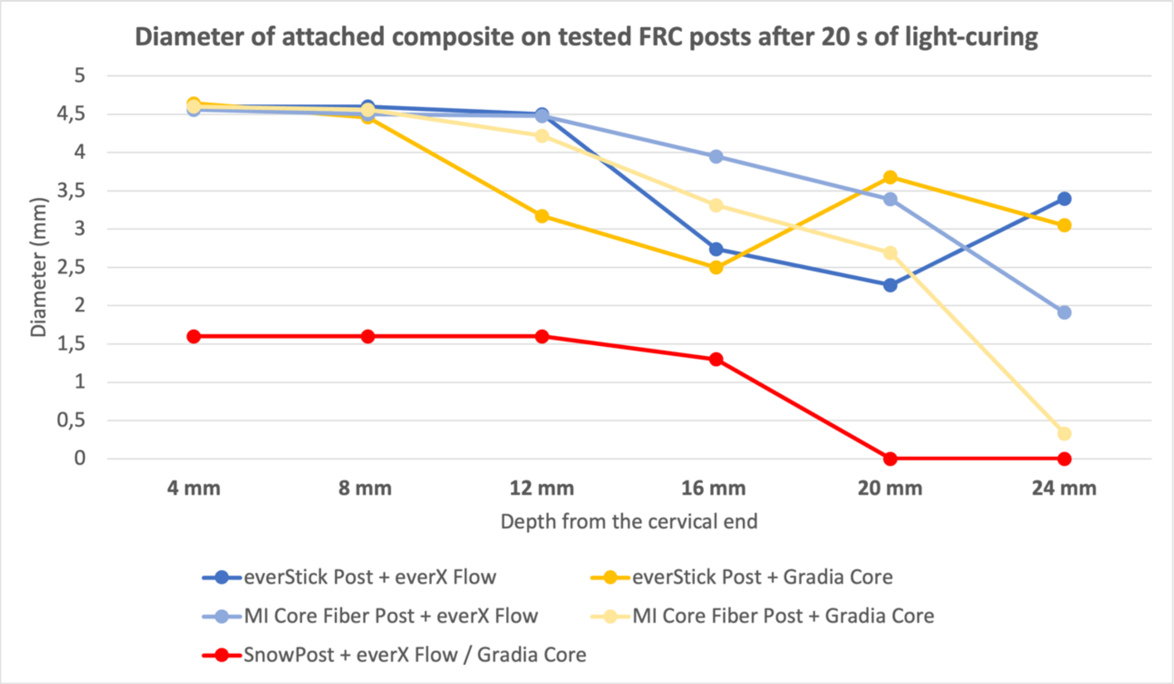

Figure 8a. The average diameter of attached composite (mm) on the tested FRC posts at different depths (mm) after 20 seconds of light-curing and scraping.

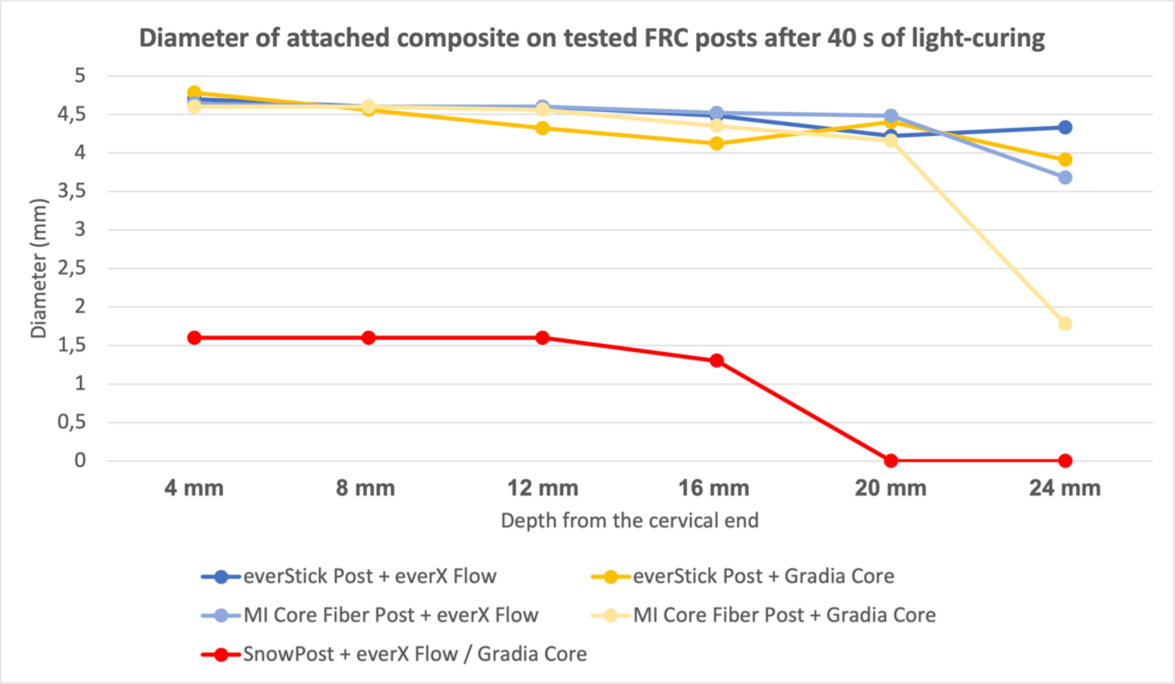

Figure 8b. The average diameter of attached composite (mm) on the tested FRC posts at different depths (mm) after 40 seconds of light-curing and scraping.

Table 2. Measured diameters of polymerized cement (mm) after the experimental procedure.

	Distance from the cervical end					
Group	**4 mm**	**8 mm**	**12 mm**	**16 mm**	**20 mm**	**24 mm**
Snowpost (all composite groups)	1.6	1.6	1.6	1.3	0	0
MI Core Fiber Post + everX Flow 20s	4.56	4.5	4.48	3.95	3.39	1.91
MI Core Fiber Post + everX Flow 40s	4.64	4.6	4.6	4.52	4.48	3.68
MI Core Fiber Post + Gradia Core 20s	4.6	4.56	4.22	3.31	2.69	0.33
MI Core Fiber Post + Gradia Core 40s	4.6	4.6	4.56	4.35	4.16	1.78
everStick Post + everX Flow 20s	4.6	4.6	4.5	2.74	2.27	3.4
everStick Post + everX Flow 40s	4.7	4.6	4.6	4.48	4.22	4.33
everStick Post + Gradia Core 20s	4.64	4.46	3.17	2.5	3.68	3.05
everStick Post + Gradia Core 40s	4.78	4.56	4.32	4.12	4.4	3.91

Discussion

This in vitro study evaluated the amount and distribution of two resin composites bonded to three types of FRC posts with different polymer matrices. The MI Core Fiber Post and everStick Post groups showed significantly higher amount of attached composite on the post surface, as well as larger composite diameters around the posts at various depths from the cervical end, compared to the Snowpost group. This indicates better light transmission ability of everStick and MI Core Fiber Posts compared to Snowposts. The results from the Snowpost groups confirm the functionality of the experimental setup used: no composite was bonded to the Snowposts, indicating minimal light transmission ability through the post matrix. This also suggest that the light did not leak by the putty (Figure 7a and 7b).

In addition, the individually formed everStick Post, with both composites everX flow and Gradia Core, exhibited a noticeably larger amount of composite attached to its apical regions (depths of 24 mm), compared to the other post groups (Figures 6, 8a and 8b). This was seen especially in the 20 second light-curing group (Figures 6 and 8a). This suggests that everStick posts allowed more effective light transmission along the length of the post. Conversely, MI Core Fiber Post scattered light more than everStick posts. Considering the challenges of bonding in the apical parts of the root canal previously outlined in the introduction, the results of this study indicate that individually formed everStick Posts may provide a bonding advantage in the apical area of a root canal, where polymerization and adhesion are typically more difficult to achieve[17]. These findings of exceptional light transmission of the individually formed everStick Post are in agreement with earlier results[10,11].

The results in this study confirm the research hypothesis as no significant difference was observed in the amount of composite attached to the post surfaces between the two composite materials.

These results indicate that the composite may be adequately polymerized by light transmitted through the post only. Therefore, it may be concluded that light-cure composites can be considered as a viable option for luting fiber posts into root canals, when using posts with sufficient light-transmitting properties. In addition, the variation in the amount of adhered composite between different light-curing times highlights that long enough curing time is crucial for achieving proper polymerization of the composite around fiber posts.

Moreover, studies have previously shown that when using dual-cure composites in post cementation, the mechanical properties of the composite improve when light-curing is applied in addition to chemical polymerization[1]. These findings, combined with the results of this study, suggest that in clinical use, posts with good light transmission ability can lead to better bonding to root canal dentin.

Previous research has shown that the composition of resin composites influences their optical properties. As polymerization of the individually formed fiber post progresses, the refractive index of the resin matrix increases, which in turn improves light passing from glass fibers to the matrix of the fiber post[18]. Theoretically, a difference in refractive index between the post and the composite cement may also impact light transmission at their interface, thereby influencing the amount of composite that attaches to the post surface. Simply put, when the refractive index of the composite exceeds that of the post surface, light can pass efficiently across the interface. In this study the resin composite on the surface of fiber post was studied and therefore curing light is transmitted and only to minor extend scattered from the fiber post to resin composite. As a result, light may not effectively enter to the surrounding composite. These factors suggest that the optical properties of the composite cement and the post–cement combination can significantly affect the outcome when using light-cured composites for luting fiber posts.

As part of a laboratory study, FRC posts were prepared by manually scraping the composite with a spatula and wiped with ethyl alcohol to evaluate the amount and location of polymerized resin cement on their surfaces. Variations in the applied scraping and wiping force may have caused minor discrepancies in the results of this study. This technique has previously been applied in laboratory settings for testing filler composites (Adapted depth of cure test ISO 4049).

This study showed that the amount and depth of polymerized composite around the fiber posts depend on the light-transmitting properties of the fiber post. The results support the use of light-cure short fiber-reinforced composites for post cementation when using posts with sufficient translucency. In addition, the results emphasize the importance of adequate light-curing time and material compatibility. However, the degree of conversion of the composite was not assessed in this study, despite its critical role in the success of luting and bonding. Further research is therefore needed.

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