Original Article

Effect of Light Intensity on the Degree of Conversion of Dual-cured Resin Cement at Different Depths with the use of Translucent Fiber Posts

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Abstract

Objectives: To evaluate the effect of different light intensities on the degree of conversion (DC) of dual-cured resin cement at different depths of translucent fiber posts.

Materials and Methods: Thirty translucent fiber posts were randomly assigned into three (n=10) groups. They were cemented in the simulated canal spaces using Duo-Link dual-cured resin cement. The cement was light-cured under 600, 800 and 1100 mW/cm^2 light intensities for 40 seconds. DC of the resin cement was calculated at cervical, middle and apical thirds using the spectra of FT-Raman spectrometer. Data were analyzed by repeated measurement ANOVA and Tukey's post hoc tests (α=0.05).

Results: In all the groups, the least DC was obtained at the apical region. There were no significant differences in the DC with different light intensities between the cervical and middle regions (p>0.05). However, in the apical region, the DC in both 800 and 1100 mw/cm^2 was similar (p>0.05), but greater with 600 mW/cm^2 light intensity (p=0.02 and p<0.001, respectively).

Conclusion: In comparison with the light intensity of 600 mW/cm^2, the light intensity of 800 mW/cm^2 significantly increased the DC of dual-cured resin cement in the apical region. However, DC was not significantly different between 800 and 1100 mw/cm^2 light intensities. If the resin cement, especially in the apical areas is not sufficiently cured, microleakage might increase and post retention might be jeopardized. In comparison with 600 mW/cm^2 light intensity, 800 mW/cm^2 significantly increases DC at the apical third that might be clinically beneficial.

Key Words: Resin Cements; Light Curing of Dental Cements; Polymerization; Fiberglass Reinforced Polymers

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INTRODUCTION

Use of fiber posts has gained widespread popularity for the restoration of endodontically treated teeth that have lost a large amount of coronal structures [1]. This popularity has been attributed to the esthetic appearance of fiber posts and the similarity between the modulus of elasticity of fiber posts and those of dentin and resin cements [2,3]. Contrary to opaque posts, translucent fiber posts can transmit light; therefore, they can increase polymerization of dual-cured resin cements and also the curing depth [4-6] However, even translucent fiber posts can reduce light transmission to less than 40% and might not guarantee sufficient polymerization of resinous materials [7].

When light is irradiated into a post, there is a significant decrease in the light intensity because of light scattering within the post and the resin cement and shadows produced by tooth and post structures [8]. Therefore, it is not a good idea to use light-cured resin cements for the cementation of fiber posts within the root canals [9]. In this context, the use of dual-cured resin cements, which have a combination of the characteristics of self-cured and light-cured resin cements, has been recommended [10]. However, research has shown that dual-cured resin cements still depend on light for adequate curing [7,11,12] One way to overcome such a problem is to increase the exposure time. Nevertheless, studies have shown that dental practitioners tend to cure composite resins for very short times [13].

No studies to date have evaluated the effect of increasing light intensity on the DC of dual-cured resin cements cured through translucent fiber posts within the root canals. Therefore, the aim of the present study was to evaluate the effect of different light intensities on the DC of dual-cured resin cements at different depths through translucent fiber posts.

MATERIALS AND METHODS

A total of 30 molds were prepared from Speedex (Coltene/Whaledent AG, Altstätten, Switzerland) condensational silicon impression material in a putty consistency to simulate the root canal space so that the posts could be covered with resin cement and could be easily removed from the canal space for evaluation of their DC. First, the fiber post (DT Light Post Illusion, Bisco, Schraumburg, IL, USA) was abraded using 600-grit Silicon Carbide paper along its long axis to produce a flat surface in the middle of the post. This was done because the spectrum acquisition of a flat resin surface is better evaluated compared to a curved surface. Then a thin plastic plate (1 mm thick) was pasted on the abraded flat surface of the post using cyanoacrylate glue (Miteapel, Beta Chemical Ind. & Trade Inco. Co., Istanbul, Turkey) to produce a space for the resin cement. Subsequently, the prepared post was placed within the impression material in plastic cylinders up to a depth of 10 mm so that root canal-shaped spaces were produced after the posts were removed from the impression materials [14]. The cement space in this study was 1 mm thick and was intentionally larger than that in the clinical situation [14,15]. The plastic plate was removed from the post surface and the post was cut to the proper length of 10 mm. The samples were randomly divided into three groups of 10. In group 1, the base and catalyst of shade A1 Duo-Link dual-cured resin cement (BISCO Inc., Schaumburg, Illinois, USA) were mixed and the cement was placed within the mold using #40 lentulo spiral (Dentsply, Maillefer Instruments SA, Ballaigues, Switzerland). The post was placed inside the mold with a gentle hand pressure and the excess cement was removed using a microbrush (Microbrush Co., Greyton, WI, USA).

Then the resin cement was light-cured using low-power Astralis 7 light-curing unit (Ivoclar Vivadent, Leichtenstein) at a light intensity of 600 mW/cm^2 for 40 seconds [14,15]. The tip of the light-curing unit was in contact with the exposed post and parallel to the long axis of the post so that the radiant light could be transmitted through the post [15]. The intensity of the light output was constantly checked by a radiometer (Coltene Whalodent AG, Altstätten, Switzerland] during the experiment [14,15].

In groups 2 and 3, all the steps were similar to those in group 1 except that Astralis 3 (Ivoclar

Vivadent, Liechtenstein] and high-power Astralis 7 (Ivoclar Vivadent, Liechtenstein) light-curing units were used at light intensities of 800 mW/cm^2 and 1100 mW/cm^2, respectively. After light-curing procedures, the molds were stored in distilled water at 37°C for 24 hours in black closed containers to prevent penetration of light.

Then the posts were removed from the molds for Raman spectroscopy analysis.14 Fourier Transform Raman (FT-Raman) spectrometer (ALMEGA Dispersive Raman, Thermo Nicolet, USA) was used to determine the spectra of the cured and uncured resin cement. A Nd:YAG defocused laser source with a wave length of 1064.1 nm was used to excite the spectra.

The maximum laser power was approximately 100 mW at a spectrum resolution of 4 cm1 using 32 scans in the range of 1590 cm1 to 1600 cm1.

The spectrum was acquired at three different depths of the cement on the post, cervical (at a distance of 3 mm from the top end of the post, middle (at a distance of 6 mm from the top end of the post), and apical (at a distance of 9 mm from the top end of the post). Degree of conversion (DC%) was determined from the ratio of absorbance intensities of aliphatic C=C bonds (peak at 1638 cm-1) against an internal standard aromatic C...C bonds (peak at 1608 cm-1), in each spectrum before and after curing of the specimen.

$$DC\% = \left[1 - \frac{(1638cm^{-1}/1608cm^{-1})\text{ peak area after curing}}{(1638cm^{-1}/1608cm^{-1})\text{ peak area before curing}}\right]\times 100$$

Levene's test and Q-Q plot were used to evaluate the equality of variances and normality of data, respectively.Data were analyzed by repeated measurement ANOVA and Tukey's post hoc test using SPSS 15 statistical software. Statistical significance was set at p< 0.05.

RESULTS

Table 1 describes the DC mean values and standard deviations in experimental groups. Data were distributed normally according to the results of Q-Q plot and the equality of variances was proved by the results of Levene's test (p>0.05).

According to the results of this study, there were significant differences in the DC of samples cured with 600 mW/cm^2 and 800 mW/cm^2 light intensities (p=0.008) and also with 600 mW/cm^2 and 1100 mW/cm^2 light intensities (p<0.001). However, there were no significant differences in the DC of specimens cured with light intensities of 800 mW/cm^2 and 1100 mW/cm^2 (p>0.05).

Two-by-two comparison of the DC of the dual-cured resin cement at different depths with Tukey's post hoc test revealed significant differences between the DC of all the three coronal, middle and apical thirds of the root (p=0.01, p<0.001 and p<0.001, respectively).

Repeated measurement ANOVA revealed no significant differences in the DC at similar depths between different light intensities at the cervical and middle thirds with the use of one-way ANOVA (p>0.05). However, the difference was significant in the apical third (P<0.001) (Table 1). Two-by-two comparison of the DC in the apical region under different light intensities with the use of Tukey's post hoc test revealed significant differences between the light intensities of 600 mW/cm^2 and 800 mW/cm^2 (p=0.02) and also between 600 mW/cm^2 and 1100 mW/cm2 (p<0.001). However, the difference between the light intensities of 800 mW/cm^2 and 1100 mW/cm^2 was not statistically significant (p>0.05).

DISCUSSION

It is believed that light activation is still necessary to increase the polymerization rate of dual-cured resin cements despite the independence of light-curing and self-curing processes [10,14,15,17]. Considering the ability of light transmitting through translucent fiber posts, in the present study, the DC of dual-cured resin cement at various depths (cervical, middle and apical) was evaluated under different light intensities (600, 800, and 1100 mW/cm^2) cured via transmission of light through translucent fiber posts in simulated root canals using FT-Raman spectrometer.

Based on the results of the present study, DC of the specimens cured by the light intensities of 800 mW/cm^2 and 1100 mW/cm^2 were significantly higher than those cured by the light intensity of 600 mW/cm^2. However, DC was not significantly different between 800 and 1100 mw/cm^2 light intensities. According to previous studies, a higher light intensity results in a higher DC in dual-cured resin cements [18-22]. Higher light intensity results in a higher peak in the wavelength of 470 nm and activation of more camphoroquinone molecules.

As a result, more free radicals are produced and monomers are converted into polymers more rapidly, resulting in a higher DC in a shorter time. Cerutti et al. [20] showed that different curing techniques (combinations of different light intensities and curing times) have a significant effect on the DC of the specimens despite having the same energy density. It was also shown that the effect of time and light intensity on DC is material-dependent.

Nevertheless, some studies have shown results opposite to the results of the present study [23-25]. Komori et al. [26] showed that curing with QTH light-curing unit does not result in significant differences in the DC and KHN at light densities of 10, 20 and 30 J/cm^2; however, curing with LED light-curing units revealed a significant decrease in the DC at a light density of 10 J/cm^2. In comparison to the present study, Calheiros et al. [25] applied different energy densities to cure hybrid and microfilled composite resin materials with a filler load of 40-60% and reported no significant increase in the DC when a higher dosage of light energy was used. In addition, a higher dosage of light energy resulted in a significantly dramatic increase in the shrinkage stress. Another significant finding of the present study was that the DC in the coronal third was higher than that in the middle and apical thirds and the DC in the middle third was also higher than that in the apical third, leading to the lowest degree of conversion in the apical third. Light intensity quantity decreases from the coronal third toward the apical third as it is transmitted through fiber posts [6,27-29]. With a decrease in the light intensity at higher depths, the amine present in the base of the paste and the peroxide in the catalyst exhibit lower efficacy for the self-curing reaction.

Table 1. Mean Values (%) and Standard Deviations (Mean ± SD) of the Degree of Conversion in the Study Groups

Depth	**Light Intensity**		
	600(1)	**800(2)**	**1100(3)**
Coronal	$77.95^a \pm 11.20$	$81.25^a \pm 12.57$	$82.40^a \pm 16.32$
	$p_{(1,2)}= 0.56$	$p_{(2,3)}=0.50$	$p_{(1,3)}=0.81$
Middle	$66.40^a \pm 12.05$	$75.61^a \pm 21.87$	$72.77^a \pm 12.33$
	$p_{(1,2)}= 0.29$	$p_{(2,3)}=0.77$	$p_{(1,3)}=0.25$
Apical	$36.30^b \pm 6.30$	$53.68^b \pm 17.65$	$65.73^b \pm 10.33$
	$p_{(1,2)}= 0.02$	$p_{(1,3)}<0.001$	$p_{(2,3)}=0.07$
Total	$60.22^A \pm 20.37$	$70.18^B \pm 20.98$	$73.63^B \pm 14.53$

Different capital means significant differences in the DC of specimens cured with different light intensities.
Different lower letter means significant differences in the DC of specimens cured with different light intensities at different regions of post space.

There is a strong relationship between the ability of the fiber post in transmitting light and the DC of dual-cured resin cement [15]. Therefore, in the present study, the decreased DC of the resin cement at the apical area compared with the cervical area is explained that is consistent with the results of the studies conducted by Kim, Feria Silva and Cerutti [14,15,20]. In addition, based on the results of a study carried out by Yoldaş and Alaçam [5], the hardness of composite resin decreases along the root during cementation of the translucent fiber posts. In contrast, Pereira et al. [30] demonstrated that the means of the DC did not reveal significant differences in different parts of the translucent DT Light Post space. The reason may be due to different adhesive systems used in conjunction with dual-cured resin cement. They used 3-step etch-and-rinse and one-step self-etch adhesive systems. However, in the present study, dual-cured resin cement was applied in conjunction with 2-step etch-and-rinse adhesive system.

In the present study, the range of DC at 600 mW/cm^2 was 36.3–77.95%, which was similar in the apical region to that of a study by Feria e Silva et al. [14]; however, the results of the present study revealed higher DC values in the cervical region compared to the above-mentioned study (69.8%) because they placed the light-curing tip at an angle of 45º, possibly affecting the intensity of light received by the cement. In addition, the results of the present study showed that the degree of conversion in the apical region at light intensities of 800 mW/cm^2 and 1100 mW/cm^2 was higher than those under light intensity of 600 mW/cm^2. However, the differences between the light intensities of 800 mW/cm^2 and 1100 mW/cm^2 were not significant.

It has been reported that in the QTH light-curing units, when the distance between the light source and the composite resin exceeds 6 mm, the intensity of the light output becomes less than 1/3 of the main output of the unit [31]. Ho et al. [27] reported that polymerization of the resin cement beyond 5 mm decreases significantly with the use of all various fiber posts. However, the results of the present study showed that when translucent posts and light intensities higher than 600 mW/cm^2 are used, an acceptable degree of conversion is achieved at distances exceeding 6 mm. Galhano et al. [32] reported that translucent posts make it possible to polymerize cements up to the middle portion of the root (8 mm). Nomoto et al. [19] reported that the minimum light energy to achieve the saturation DC is 1000 mW/cm^2 and there is a linear relationship between the DC and log of exposure and also between the curing depth and log of light energy. If the resin cement within the root canal, especially in the apical areas is not sufficiently cured, microleakage might increase and post retention might be jeopardized, threatening the longevity of the restoration and the tooth [27,33]. Despite a direct relationship between the DC of the resin cement and an improvement in mechanical properties, care should be taken not to attribute the clinical success to the DC only; other factors should also be taken into account because DC is not the only determinant of clinical performance [14,17].

Furthermore, it should be taken into account that the monomers remaining in the partially cured resin cement might leak through the apical foramen and cause harmful effects on the periodontal tissues [34, 35]. Inadequate curing of the cement in deep areas results in the release of monomers, leading to toxic effects and decreasing the desirable properties of the resin cement. Therefore, adequate polymerization of the resin cement is desirable to improve its biocompatibility and curing at deep areas is absolutely necessary and very important [36-41]. In the present study, the cement had a uniform thickness of approximately 1 mm. Since this thickness is more than that of the cement in clinical situations, it is probable that in thinner resin cement the DC will be different to some extent.

Besides, in the present study one type of dual-cured resin cement was evaluated; therefore, other resin cements might yield different results depending on their self-curing and light-curing properties. In addition, in the present study the tip of the light-conducting device was in direct contact with and perpendicular to the fiber post, while in clinical situations there might be some distance between the tip of the device and the post or it might not be perpendicular to the post and the limitations caused by the teeth and adjacent tissues may lead to a detrimental effect on the DC. Therefore, it is suggested to carry out similar studies in clinical situations to evaluate the effect of limitations produced by tooth structures and adjacent tissues on the degree of polymerization.

CONCLUSION

In comparison with the light intensity of 600 mW/cm^2, light intensity of 800 mW/cm^2 significantly increased the degree of conversion of Duo-Link resin cement in the apical region of the post space. However, the degree of conversion was not significantly different between 800 and 1100 mw/cm^2 light intensities.

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