

## Masking of temperature-induced color changes in a thermo-sensitive fiber post

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**ABSTRACT: Purposes:** To evaluate (1) the efficacy of the color changing technology featured by DT Light Illusion Post aimed at safely identifying the post in case of re-treatment, and (2) the efficacy of a resin composite layer to mask the post if color shift occurs due to cold food and beverages. **Methods:** Five "master disks" of 3 mm of thickness were prepared by embedding in a resin composite four thermo-sensitive posts and one translucent post (control) cut in bars. Disks of resin composite in 0.5/1.0/1.5 mm thickness were prepared as well. Digital images were taken of the master disks with and without the overlying of the resin composite disks, at 5°C and at 35°C temperature. By the use of Adobe Photoshop "layering function" and "multi-layer option", differences in color were calculated between the post-free and the post-containing areas. **Results:** The differences between the resin color and post color were remarkably higher when the temperature was 5°C, showing that the technology of color change of the post was effective. With resin disk overlaid, at 35°C none of the differences in color were above the threshold for clinical acceptability. At 5°C blue and black colored posts were visible when the overlaid resin thickness was 0.5 mm, while at 1.0 mm and 1.5 mm none of the posts were visible. (*Am J Dent* 2012;25:123-128).

**CLINICAL SIGNIFICANCE:** Thermo-sensitive color pigment technology of DT Light Post Illusion was effective in selectively differentiating the post by lowering the temperature, useful in case of endodontic re-treatment. Color changes due to cold food and beverage consumption were not visible if at least 1 mm of resin composite was layered over the post.

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### Introduction

The use of fiber-reinforced composite (FRC) posts for the restoration of endodontically treated teeth is nowadays supported by reliable clinical evidence.<sup>1-6</sup> The clinical success of fiber post application is mainly related to their favorable mechanical behavior similar to that of natural dental tissues. In particular, the modulus of elasticity of fiber posts is similar to that of dentin, allowing for a more homogeneous stress distribution in comparison with the stress generated in the presence of materials with different elastic properties, such as metallic posts.<sup>7,8</sup> This allows the conversion of the failure risk from vertical fractures to debonding, a type of failure more easily recoverable.<sup>9-11</sup> The first FRC posts introduced on the market were based on carbon fibers, pre-tensioned and longitudinally placed in an epoxy resin matrix.<sup>12</sup> Notwithstanding the good clinical performances shown over time, FRC posts based on carbon fiber were progressively abandoned and replaced with other types of fibers. The main reason for this replacement was the black color of the post, which limited the possibility to have a tooth colored restoration, particularly important in case of metal-free prosthetic rehabilitation.<sup>13,14</sup> Nowadays, the great majority of the FRC posts marketed are composed of quartz or glass fibers, embedded in a matrix of epoxy or methacrylate resin.<sup>15</sup> Even if tooth-colored FRC have almost completely replaced black-colored carbon fiber posts, the trend is the use of translucent posts. These posts have been marketed with a two-fold objective: first, to improve esthetics by obtaining a tooth colored abutment, similar to tooth-colored opaque posts;<sup>13,14</sup> and second, to improve light transmission to the apical third of the post space, supposedly increasing the depth of curing of photo-activated resin com-

posite.<sup>16-19</sup> Another claimed advantage of FRCs when compared with cast post and cores is the easier removal of the post if an endodontic re-treatment is necessary.<sup>20,21</sup> Nevertheless, due to the tooth color appearance, identification of a FRC post upon removal may not be straightforward.<sup>21</sup>

Recently, fiber posts containing thermo-sensitive colored pigments (DT Light Post Illusion<sup>®</sup>) were introduced in the market, with a twofold aim: first, to facilitate the selection of the post diameter through the intrinsic color code rather than through colored rings or ends; and second, in case of re-treatment, to facilitate the post identification during removal. In these posts, a thermo-sensitive pigment technology induces a color change when the temperature is lowered by air-blowing and/or water cooling.

Since in the mouth temperature lowering can take place even with cold food and beverages,<sup>22</sup> the question arises whether the temperature sensitive pigment can render the post visible through a resin composite restoration as a result of the temperature decrease. FRC posts made by quartz, silica or glass fibers, combined with epoxy or methacrylate matrix are most often used to retain a prosthetic restoration,<sup>23-26</sup> but can also be used to support a direct restoration.<sup>27-29</sup> Direct resin composite restorations can be performed as the treatment of choice, as well as when the prosthetic rehabilitation has to be postponed, for economical reasons or for the need to follow up the outcome of the endodontic treatment. Whenever endodontic re-treatment may become necessary, an easily removable post would be highly desirable.<sup>29,30</sup>

The first objective of this study was to evaluate the efficacy of the color changing technology featured by DT Light Post Illusion posts. The first tested null-hypothesis was that DT Light Post Illusion posts retain a color indistinguish-



Table 1. Chemical composition, mechanical and optical properties of the investigated FRC posts.

Post	Composition	Flexural Strength (ISO 14130)	Interlaminar shear strength (ISO 14130)	Radiopacity (ISO 4049)	Size	Color
DT Light Post	Quartz stretched fibers Epoxy resin	1600 MPa	60-75 MPa	1.25-1.50 mm Al equivalent	# 1	Translucent
DT Light Post Illusion X-RO	Quartz stretched fibers Epoxy resin, catalyst, colored pigments.	1800-2000 MPa	65-70 MPa	3 mm Al equivalent	# 0.5 # 1 # 2 # 3	Black Red Yellow Blue



Fig. 1. The custom made cylindrical mold used for specimen fabrication.

able from that of the surrounding dental tissues regardless of the temperature changes. The second purpose was to assess whether post color changes occurring with temperature variations related to food and/or beverage consumption are effectively masked by resin composite. Therefore, the second tested null hypothesis was that temperature-dependent color changes of DT Light Post Illusion posts were not detectable below clinically relevant thicknesses of resin composite (0.5 mm, 1.0 mm, 1.5 mm).

### Material and Methods

Five different types of fiber posts were selected for the study. Four of them were thermo-sensitive pigment enriched posts in four shades (DT Light Post Illusion X-RO<sup>®</sup>), and the other one was a translucent post (DT Light Post<sup>®</sup>) that was used as control (Table 1). For each post type, five posts were sectioned with a water cooled Isomet<sup>®</sup> low-speed saw at 3.5 mm of distance from the coronal end, in order to obtain cylindrical post segments of 3.5 mm in length. A custom-made stainless steel mold was used for the preparation of post-containing specimens with the shape of disk ("master disk"). The mold consisted of a 15 mm-diameter cylinder with a piston inside that could be regulated to the desired thickness (Fig. 1). For the preparation of the master disk, the depth was set at 3.5 mm. Resin composite (Herculite XRV Ultra,<sup>®</sup> Enamel, A2) was applied in the mold progressively, and the

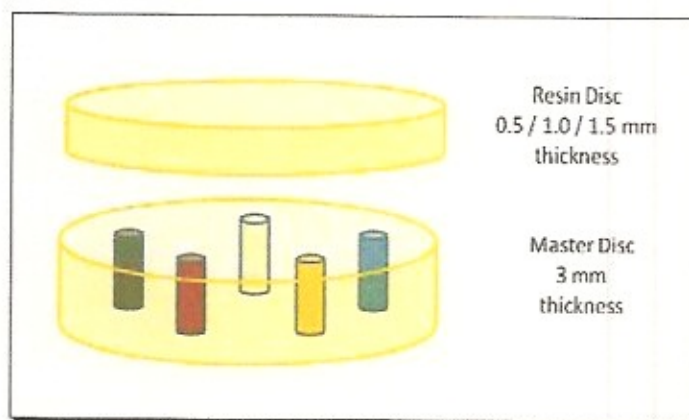


Fig. 2. Schematic representation of the experimental configuration.

posts segments were placed into the composite in a circular orientation (Fig. 2). After placing all the five post segments, the composite was light cured on the upper surface using the quartz-tungsten-halogen light (Optilux 501<sup>®</sup>) with an output power of 750 mW/cm<sup>2</sup>, checked with the curing unit internal radiometer. A light guide with 11 mm exit diameter was used. In order to obtain a proper curing of the specimen, the tip of the guide was maintained at 2 mm distance from the specimen so that the entire surface of the specimen could be irradiated. Furthermore, the curing time for the resin composite/color combination used was raised from the suggested minimal time of 20 seconds to 60 seconds. The obtained disk was then removed from the mold and polymerized again for 60 seconds on the opposite side. The upper surface was then flattened with the low-speed saw and finished with a 320-grit paper to a final height of 3 mm. Using the same mold, three disks of the same resin composite used for the master disks were prepared in three different thicknesses (0.5 mm, 1.0 mm, and 1.5 mm) (Fig. 3). For evaluating the masking ability of the composite, each of the three resin disks was placed over each of the five master disks. Images were taken with digital photo camera D80s<sup>®</sup> equipped with a Nikkor 105 mm f/2.8 AF-D Micro lens.<sup>®</sup> In order to maintain the setting constant for all the measurements, the camera was fixed on a stand. The magnification of the lens was set at x1.0, thus the distance from the front of the lens to the specimen was about 135 mm (in focus). "Manual" exposure mode was selected in the camera. F-stop was set at F=14.0 (maximal aperture at 1.0 magnification) and exposure time was set at 1/30 seconds, following the camera light meter indication. Illumination was provided by the cold light illuminator PL 2000,<sup>®</sup> with a light color temperature of 5400° K and 100W bulb power. The two light guides of the illuminator were positioned in a 45°/45° illumination geometry at a distance of about 5 cm from the



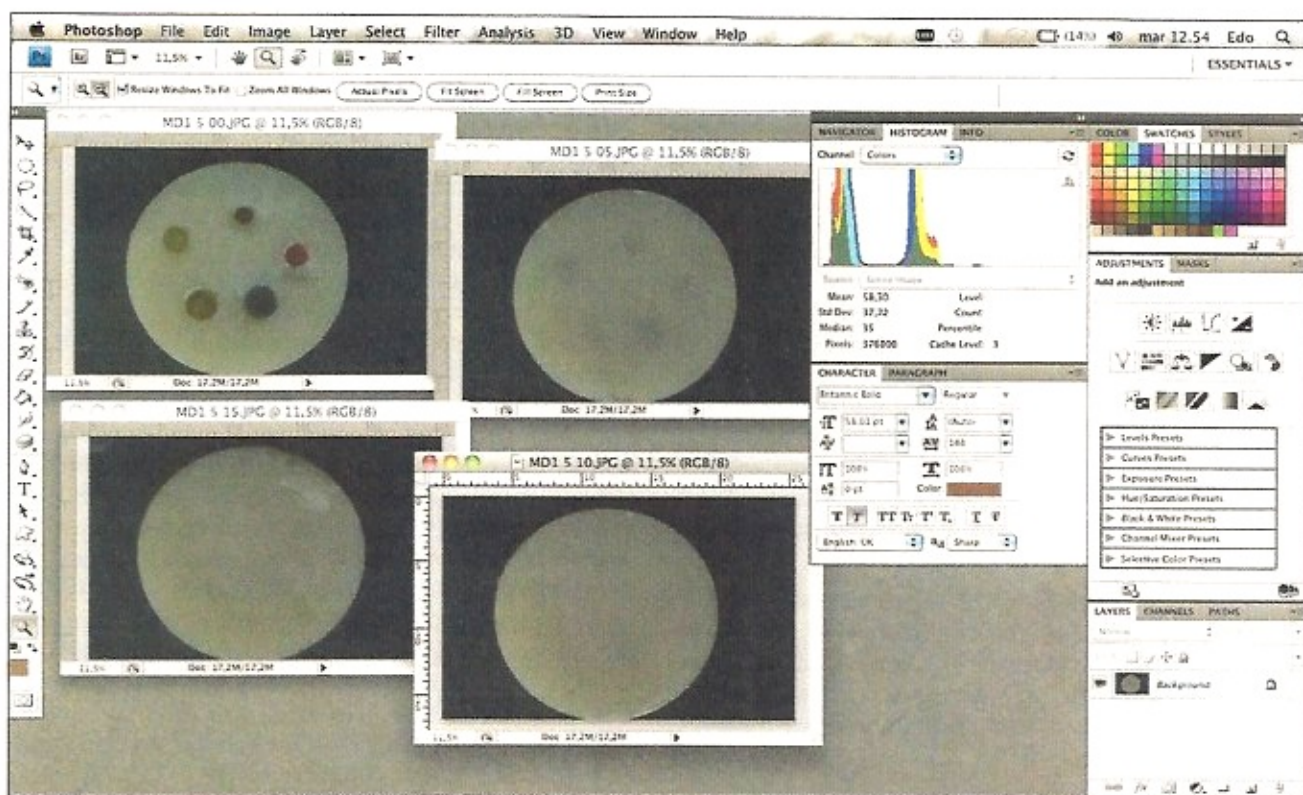


Fig. 3. Adobe Photoshop lab measurement screen with master disk without (upper left) and with covering with different thicknesses of resin layer.

Table 2. Calculated  $\Delta E$  values at 5° and at 35°.

Thickness/ Specimen	T= 5°					T= 35°							
	Transl	Black	Red	Yellow	Blue	Thickness/ Specimen	Transl	Black	Red	Yellow	Blue		
0.0	1	12.8	30.6	33.5	23.4	33.5	0.0	1	15.9	15.5	19.1	15.0	17.1
	2	12.0	28.8	33.9	22.7	33.0		2	11.9	12.5	17.2	12.4	14.8
	3	16.1	29.6	35.2	23.9	29.4		3	12.8	19.9	20.0	20.0	19.0
	4	13.1	30.6	32.3	26.2	30.9		4	13.5	14.6	14.7	17.6	14.3
	5	17.3	31.6	31.7	25.3	29.2		5	11.8	14.8	14.2	20.4	14.8
	Mean (sd)	14.3 (2.3)	30.2 (1.1)	33.3 (1.4)	24.3 (1.4)	31.2 (2.0)		Mean (sd)	13.2 (1.7)	15.5 (2.7)	17.0 (2.6)	17.1 (3.4)	16.0 (2.0)
0.5	1	1.2	3.6	3.8	2.8	4.6	0.5	1	1.3	2.1	2.7	1.2	2
	2	2.8	3.6	3.5	2	4.9		2	1.7	2.2	1.4	0.9	2.4
	3	1.8	3.8	2.7	1.3	3.5		3	1.3	2.4	1.6	1.7	2.3
	4	1.9	3.4	2.9	1.9	3.7		4	1.6	2.5	2.1	1.8	1.4
	5	1.3	2.7	2.7	2.1	3.1		5	0.6	1.6	1.7	1.3	1.8
	Mean (sd)	1.8 (0.6)	3.4 (0.4)	3.1 (0.5)	2.0 (0.5)	4.0 (0.8)		Mean (sd)	1.3 (0.4)	2.2 (0.4)	1.9 (0.5)	1.4 (0.4)	2.0 (0.4)
1	1	1.8	1.8	1.8	1.1	2.5	1	1	1.2	1.3	1.8	2.1	2.6
	2	2.2	2	2	0.9	2.3		2	2.8	1.8	1.2	1	2.6
	3	2.5	3.3	1.5	0.4	1		3	3	1.5	0.9	0.7	1.1
	4	0.6	2.7	1.7	1.3	1.5		4	0.5	2.6	1.5	0.6	1.4
	5	1.8	0.4	0.5	2.4	2.3		5	0.6	0.5	2.2	2.9	1.5
	Mean (sd)	1.8 (0.7)	2.0 (1.1)	1.5 (0.6)	1.2 (0.7)	1.9 (0.6)		Mean (sd)	1.6 (1.2)	1.5 (0.8)	1.5 (0.5)	1.5 (1.0)	1.8 (0.7)
1.5	1	1.2	1.4	1.2	1	0.9	1.5	1	1.9	1.6	1.7	1.8	1.4
	2	2.3	1.7	1.4	1	1.5		2	2.3	1.4	1.1	1	1.6
	3	1.5	1.8	0.8	0.4	0.3		3	1.9	1.6	0.8	0.6	0.5
	4	0.5	1.5	0.9	0.6	0.4		4	0.2	1.3	0.9	0.5	0.3
	5	1	1.1	2.8	0.8	2.8		5	1.5	1.8	2.4	2.3	2
	Mean (sd)	1.3 (0.7)	1.5 (0.3)	1.4 (0.8)	0.8 (0.3)	1.2 (1.0)		Mean (sd)	1.6 (0.8)	1.5 (0.2)	1.4 (0.7)	1.2 (0.8)	1.2 (0.7)

specimen. Regulations and settings were maintained constant for taking all of the images. The tests were carried out at two different temperatures (5°C and 35°C) by fixing with self-adhesive tape the post-containing disks over a glass plate placed over a thermostatic bath. The temperature of the glass plate was constantly monitored by the digital thermocouple thermometer Minitemist-N.<sup>8</sup> The digital images obtained in

TIFF format were transferred to a PC and analyzed with the use of Adobe Photoshop CS4 Extended<sup>h</sup> without any image manipulation. With use of the layering function of the software and the multi-layer option, it was possible to superimpose each image of the master disk covered by the composite disk over the image of the master-disk alone, in order to identify the post location. The spot diameter for measuring



was set at 140 pixels in order to fit within the diameter of the smallest post tested. With the function histogram values of lightness, a and b were recorded for each of the five post segments inserted into the master disk, and for the central part of the master disk that was free from post segment. Regarding lightness, the a and the b values of the histogram window were not standard CIELab\* color values, the obtained values were then converted into CIELab\* values as follow:<sup>31</sup>  $L^* = \text{Lightness}/255 * 100$ ;  $a^* = (240a/255)-120$ ;  $b^* = (240b/255)-120$ . After transforming into CIELab\* values, differences in color expressed by the  $\Delta E$  were calculated with the formula proposed by Clarke<sup>32</sup>  $\Delta E_{ab} = [(L_1-L_2)^2 + (a_1-a_2)^2 + (b_1-b_2)^2]^{1/2}$  comparing  $L^*$ ,  $a^*$  and  $b^*$  values of the central part of the master disk, free from post segment, with each of the four colored posts (DT Light Post Illusion X-RO) and with the non-colored control post (DT Light Post). Values of  $\Delta E$  higher than 3.3 were considered as clinically not acceptable.<sup>33-35</sup>

**Statistical analysis** - Since all the  $\Delta E$  values measured at 35°C were below the threshold of clinical acceptability, these data were not statistically processed. With regard to  $\Delta E$  values at 5°C the influence of thickness and post color on  $\Delta E$  was assessed with Fisher's Exact tests. In all the analyses the level of significance was set at  $P < 0.05$

## Results

Calculated values of  $\Delta E$  are reported in Table 2.

When the master disks were evaluated without the resin composite disk overlaid, at 35°C the mean of calculated  $\Delta E$  were 13.2 for the translucent control group and 15.5, 17.0, 17.1 and 16.0 for the blue, black, red and yellow Illusion posts, respectively. Thus, the differences in  $\Delta E$  values between the control group and the four colored posts at 35°C can be considered limited. Conversely, when the temperature was lowered to 5°C, the mean of calculated  $\Delta E$  values was 13.9 for the translucent control group and 30.2, 33.3, 24.3 and 31.2 for the blue, black, red and yellow Illusion post, respectively. These remarkably increased differences in  $\Delta E$  values shows that the pigment technology is efficient in clearly differentiating the post, from the composite tested in combination and thus possibly also from dental tissues.

When the resin disks were overlaid at 35°C, none of the calculated  $\Delta E$  values was above the threshold of clinical acceptability. This validates the manufacturer's claim that at oral temperature the colored pigment enriched post (Illusion) optically behaves as a conventional translucent post. Conversely, when the temperature was lowered to 5°C,  $\Delta E$  values exceeding the limit for clinical acceptability were detected.

Thickness was found to significantly influence  $\Delta E$  values at 5°C ( $P < 0.001$ ). Specifically,  $\Delta E$  beyond the threshold of clinical acceptability occurred significantly more frequently with a 0.5 mm-thick composite layer than with 1.0 mm and 1.5 mm thicknesses. Color of posts was found to significantly influence  $\Delta E$  values at 5°C ( $P = 0.037$ ). Specifically, a significantly higher frequency of  $\Delta E$  values beyond the threshold of clinical acceptability was recorded for blue and black posts than for yellow, red and translucent posts (Table 2).

## Discussion

Based on results of the present study, the first null hypothe-

ses had to be rejected. Color changing post technology was effective at inducing a color change that rendered the post clearly distinguishable from the surrounding dental tissues. Conversely, the second null hypothesis had to be partly rejected. As a matter of fact, temperature-induced color changes of DT Light Post Illusion posts were detectable below a 0.5 mm-thick layer of resin composite.

The method used for the evaluation of color in the present study is based on the analysis of digital images performed with Adobe Photoshop software. Even if highly sophisticated instruments are available for measuring color, the measurement of a translucent sample is not easy to perform. The reference instrument for such specimens is a spectrophotometer equipped with an integrating sphere.<sup>36</sup> Unfortunately, a small aperture integrating sphere is not commonly available and the size of the reading aperture of routinely commercially available integrating spheres is generally 0.3-0.5 inches. This is not feasible when specimens of a smaller diameter, as well as small spots have to be measured, as in the case of the present study. Digital imaging devices and software that can quantify color coordinates may represent an alternative solution. This software has been used in dentistry for several purposes, such as communication between dentist and dental lab, documentation, patient education as well as for color measurement and shade match.<sup>37-39</sup> In particular, Adobe Photoshop software has a large diffusion and may represent an alternative for this kind of measurement.<sup>31</sup> Effectiveness of Adobe Photoshop for this measuring purpose has been validated by the International Standards Organization which indicated this software for digital imaging measurements of equidensity in radioopacity assessment for dental materials, even if these last are on a grayscale basis.<sup>40</sup>

The thermo-sensitive pigments used for the Illusion post proved to be effective at changing the color of the posts. This was demonstrated by the finding that difference in  $\Delta E$  values between the color of the composite (A2) and post color was significantly larger at 5°C than at 35°C. The 35°C temperature was selected as body temperature,<sup>41</sup> while the 5°C temperature was selected as the temperature conventionally used for thermo-cycling and considered as the lowest temperature that can be comfortably maintained in the mouth during food or beverage consumption.<sup>41</sup>

The color changing technology could be helpful in case of re-treatment. In fact, it is known that a certain percentage of endodontic re-treatment is necessary due to the development or reappearance of periapical pathology.<sup>42-44</sup> Abbot<sup>45</sup> found that one third of patients completing endodontic re-treatment had previously placed posts removed from the root canal, and Grandini<sup>46</sup> reported that this percentage has very likely increased in the last decade due to the widespread use of metal and fiber posts. In case an endodontic re-treatment is needed in a posted root, the procedure of post removal may be challenging and unsuccessful.<sup>21</sup> Post removal requires finding the way down along the post and hollowing out the post itself. However, identifying the post inside the root may not be straightforward.<sup>47</sup> The first generation of fiber posts were carbon-based. As their color was black, they were easily distinguishable from dental tissues. The structure of Light Post and Illusion post consists of stretched parallel fibers in a



resin matrix. The parallel fibers help removal drills and burs remain within the confines of the post, reducing the risk of perforation, and special kits have been developed for this purpose.<sup>47</sup> Indeed, the tooth-like aspect of esthetic fiber posts may be a disadvantage in case of re-treatment. For this reason, fiber posts containing thermo-sensitive pigments have been recently marketed. At body temperature they appear as traditional translucent posts while at low temperatures they undergo a color shift. Lowering of temperature can be attained by blowing and/or with water cooling, necessary during high-friction post hollowing, which exposes the periodontal ligament to elevated temperatures.<sup>47</sup>

Regarding post color changes induced by consumption of cold food and beverages, it should be considered that composite coverage of the exposed post is recommended anyway for protecting the post surface from exposure to oral fluids. The concern has indeed been raised that oral fluids may be responsible for hydrolytic degradation phenomena that might weaken the post structure over time.<sup>48,49</sup> Overlaying the post with resin composite has been demonstrated to be sufficient to seal the post end thus avoiding hydrolytic degradation.<sup>50</sup> The data collected in the present study showed that only two colored posts were visible through the restoration and only when covered by a layer of composite as thin as 0.5 mm. A 1.0 mm-thick composite layer placed over the post was enough to effectively mask the underlying colored post even in case of color shift, taking the  $\Delta E$  values under  $\Delta E=3.3$  limit for clinical acceptability.

In conclusion, the thermo-sensitive pigment technology used in the Illusion post was effective at differentiating the post from the tooth-colored resin composite when the temperature was lowered to 5°C. A 1.0 millimeter thickness of the composite used sufficiently masked all color changes.

- a. RTD, Egreve, France.
- b. Buehler, Lake Bluff, IL, USA.
- c. Kerr Co, Orange, CA, USA.
- d. Kerr Co, Danbury, CT, USA.
- e. Nikon Co, Tokyo, Japan.
- f. Photonic, Vienna, Austria.
- g. LSI Salmoiraghi, Milan, Italy.
- h. Adobe System Inc, San Jose, CA, USA.

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### Articles Accepted for Publication

- **Long-term efficacy of in-office and at-home bleaching: A 2-year double-blind randomized clinical trial.**  
*L.Y. Tay, C. Kose, D.R. Herrera, A. Reis & A.D. Loguercio*
- **Azithromycin as an adjunctive treatment of aggressive periodontitis: Radiographic findings of a 12-month randomized clinical trial**  
*A.N. Haas, F. Seleme, P. Segatto, C. Susin, J. Albandar, R.V. Oppermann, V.R. Fontanella & C.K. Rosing*
- **Fluoride plus CO<sub>2</sub> laser against the progression of caries in root dentin.**  
*V. Colucci, D.C.F. Messias, M.C. Serra, S.A.M. Corona & C.P. Turssi*
- **Contemporary adhesives: Marginal adaptation and microtensile bond strength of class II composite restorations.**  
*R. Takahashi, T. Nikaido, J. Tagami, R. Hickel & K-H. Kunzelmann*
- **Enamel and dentin bond strength of a new simplified adhesive materials with and without preliminary phosphoric acid-etching.**  
*J. Juloski, C. Goracci, C. Rengo, A. Giovannetti, A. Vichi, Z.R. Vulicevic & M. Ferrari*
- **Effect of acid etching time on demineralization of primary and permanent coronal dentin.**  
*D.L.S. Scheffel, L.M.A. Tenuta, J.A. Cury & J. Hebling*