

RESEARCH AND EDUCATION

## Influence of interim cements on the optical properties of interim restorations



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The development and improvement of adhesive techniques has allowed the use of more conservative restorative procedures such as porcelain laminate veneers, which require minimum removal of sound tooth tissue and result in extremely thin restorations.<sup>1-3</sup> Restorative procedures that involve laminate veneers are often associated with interim restorations.<sup>4</sup> Although bis-acrylic resins have been widely used, some situations demand esthetic restorations with acrylic resins. In these cases, shade selection is based on the neighboring or homologous teeth to create a favorable esthetic result.<sup>5-7</sup> However, even if an appropriate shade of the material is chosen for the interim restoration, the final color of the restoration is significantly affected by the color and translucency of the underlying material.<sup>8-10</sup>

Another optical characteristic that may interfere with the esthetic result of restorations is fluorescence, which is the visible light emitted when the teeth are illuminated

### ABSTRACT

**Statement of problem.** Even if the appropriate resin shade is selected for an interim restoration, how the optical characteristics of the interim cement affect the esthetics of the interim restoration is unclear.

**Purpose.** The purpose of this in vitro study was to evaluate the effects of interim cements on the optical properties of interim restorations.

**Material and methods.** Twenty dentin disks (6×1 mm) were obtained from the labial surface of bovine incisors. Disks of acrylic and bis-acrylic resins (n=20) with the same dimensions were prepared and cemented over the dentin using the following cements: Bifix Temp (resin-based; VOCO), ClearTemp LC (resin-based; Ultradent Products, Inc), Provicol (VOCO), TempCem NE (Coltène). The same dentin and resin disks were used for all cements. After cementation, the color difference ( $\Delta E_{00}$ ), translucency parameter (TP), and fluorescence of the dentin/cement/resin combinations were compared with each other and with a control group (C), in which a transparent liquid (polyethylene glycol 400; LabSynth) was applied. Color and translucency were evaluated with a spectrophotometer (CM-2600; Konica Minolta) and fluorescence with a spectrofluorophotometer (RF-5301PC; Shimadzu).  $\Delta E_{00}$  and TP data were analyzed using 2-way ANOVA. For fluorescence, 1-way ANOVA was used. The Tukey test was used for multiple comparisons ( $\alpha=.05$ ).

**Results.**  $\Delta E_{00}$  values were significantly influenced by the interim material ( $P<.001$ ) and the interim cement ( $P<.001$ ). Bifix Temp showed the lowest significant  $\Delta E_{00}$  values ( $P<.001$ ). The highest  $\Delta E_{00}$  values were observed for TempCem NE. No differences were observed between the interim resins with respect to TP ( $P=.318$ ). The lowest translucency values were measured for TempCem NE, followed by Provicol, ClearTemp LC, Bifix Temp, and the control group ( $P<.001$ ), with no significant differences among the interim resin-based cements. Among the cements, Bifix Temp and TempCem NE yielded fluorescence similar to that of the natural tooth for both interim resins. A similar result was found for bis-acrylic resin combined with Provicol.

**Conclusions.** Cementation with interim resin-based cements resulted in better esthetics. However, the high fluorescence of the ClearTemp LC may reduce the esthetics of interim restorations in environments with predominantly UV light. (J Prosthet Dent 2019;121:821-7)

with ultraviolet (UV) light,<sup>11,12</sup> for example, in specific environments such as nightclubs.<sup>13,14</sup> Ideally, interim restorations should match the fluorescence of natural

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## Clinical Implications

Dentists should be aware that appropriate selection of interim cement and type of interim material can lead to improved esthetics. Cementation with interim resin-based cements will result in better color and translucency. However, the fluorescence of these materials may interfere with esthetics when associated with acrylic resin interim restorations.

teeth.<sup>12,15</sup> This fluorescence may be provided by the resinous material used for the interim restoration or from the interim cement. Commercially available acrylic and bis-acrylic resins are fluorescent, but some may exhibit a higher fluorescence than others.<sup>15</sup> This combined with the properties of the interim cement can produce unpredictable results. Fluorescence under a light-emitting UV source has also been used as a means of ensuring the complete removal of interim cement before cementation.

Recently, interim resin-based cements have been introduced as an alternative to conventional zinc oxide-eugenol cements because of their better optical characteristics.<sup>9</sup> However, studies determining whether these claims are valid and whether such materials can provide more advantageous esthetic results over conventional materials are lacking. Therefore, the purpose of this in vitro study was to evaluate the influence of interim cements on the color, translucency, and fluorescence of interim restorations. The null hypotheses tested were that interim cements would produce similar results to each other and that no difference would be found between acrylic and bis-acrylic resins.

## MATERIAL AND METHODS

Disks of acrylic (n=20) and bis-acrylic resins (n=20) with the same dimensions were prepared and cemented over the dentin (n=20) by using 4 cements: Bifix Temp, ClearTemp LC, Provicol, and TempCem NE (Table 1). After cementation, the color difference ( $\Delta E_{00}$ ), translucency parameter (TP), and fluorescence of the dentin/cement/resin assemblies were analyzed. A transparent liquid (PEG 400; LabSynth) was used in the control group. Specimens of dentin, enamel (n=20), pure luting agents (n=80), and interim resin were also prepared to analyze their intrinsic optical properties (Fig. 1). All materials were manipulated according to the manufacturer's instructions. The sample size was estimated using the Sealed Envelope online software ([www.sealedenvelope.com](http://www.sealedenvelope.com)). The means and standard deviation obtained in the pilot study, a level of significance ( $\alpha$ ) of 5%, and a power (1- $\beta$ ) of 80% were used.

**Table 1.** Technical information of materials used

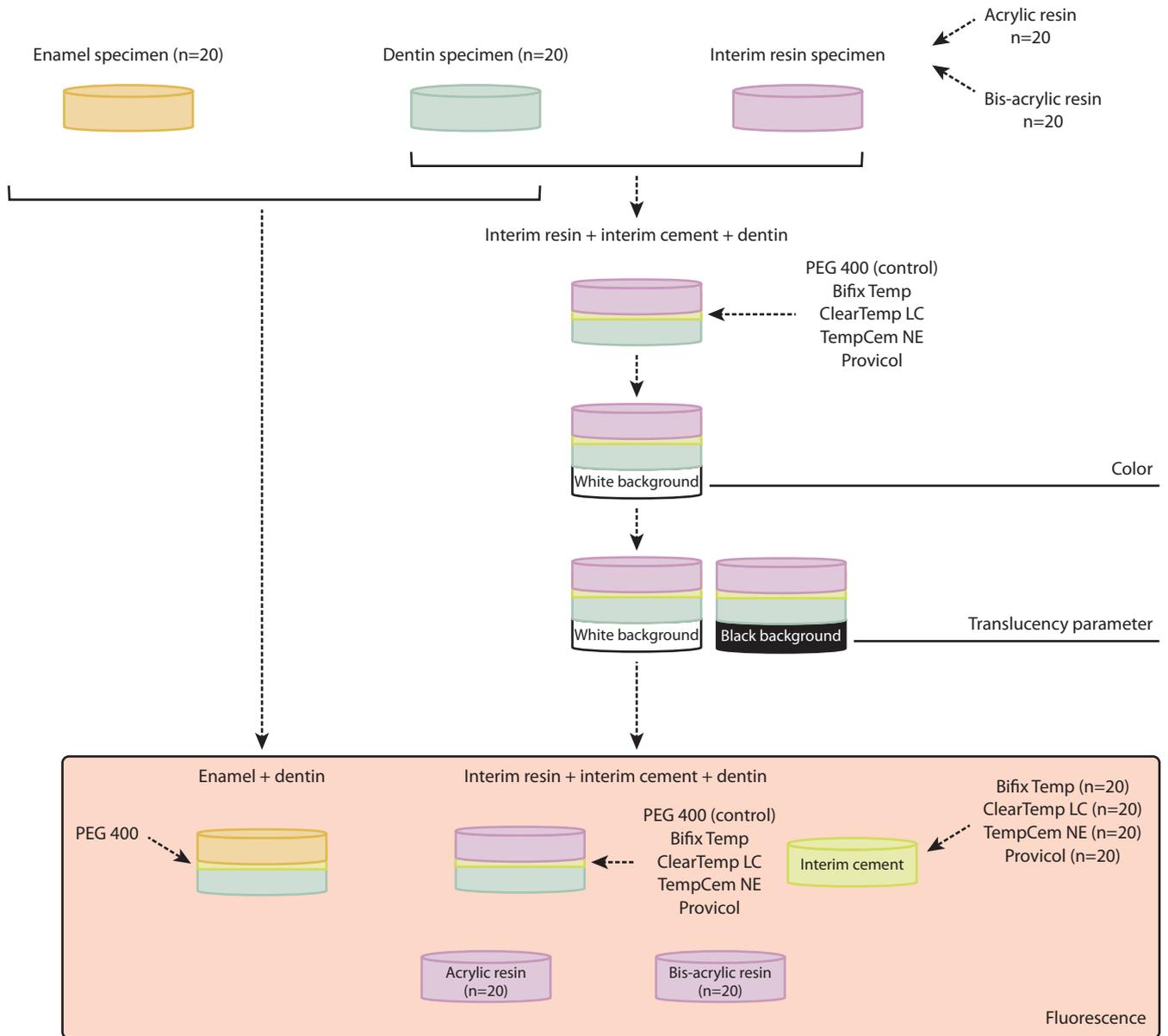
Material	Manufacturer	Composition	Batch Number
Dencôr	Clássic	Powder: polymethylmethacrylate, pigments, benzoyl peroxide; Liquid: MMA, DMT, EGDMA	710143
Structur 3	VOCO	Urethane dimethacrylate (UDMA), bisphenol A-glycidyl methacrylate (Bis-GMA), benzoyl peroxide	1541091
Bifix Temp	VOCO	Catalyst: Dimethacrylates (UDMA, TEGDMA, PEGDMA), BPO, BHT, fumed silica Base: Dimethacrylates (UDMA, TEGDMA, PEGDMA), amine, CQ, fumed silica	1516366
ClearTemp LC	Ultradent Products, Inc	Bis-GMA, triethylene glycol dimethacrylate, methacrylic acid	H018
TempCem NE	Coltène	Base: zinc oxide and vegetable oil Catalyst: ethoxybenzoic acid, dimerized resin, carnauba wax, and glacial acetic acid.	1304490
Provicol	VOCO	Base: coconut fatty acid Catalyst: zinc oxide, calcium dihydroxide, magnesium oxide, sunflower oil	1611359

BHT, butylated hydroxy toluene; BPO, benzoyl peroxide; CQ, camphorquinone; DMT, dimethyl terephthalate; EGDMA, ethylene glycol dimethacrylate; MMA, methyl methacrylate; PEGDMA, poly(ethylene glycol) dimethacrylate; TEGDMA, triethylene glycol dimethacrylate.

Twenty cylindrical specimens of enamel bovine (6 mm in diameter and 1 mm in height) and 20 cylindrical specimens of dentin bovine (6 mm in diameter  $\times$  1 mm in height) were used. For dentin, a notch was made in the portion corresponding to the deep dentin. This allowed the exact repositioning of the specimen at the time of cementation.

To simulate the interim restorations, acrylic resin (n=20) and bis-acrylic resin (n=20) disks were prepared, both of shade A2 (Table 1). A silicone mold (Rodhorsil; Clássico) was filled with the interim material and covered with a transparent polyester strip and a glass slide until the end of the polymerization. All specimens were polished with sequential silicon carbide abrasive papers (P2400 and P4000 grit) in a polishing device for 30 seconds each. In these specimens, a notch was made on 1 surface to allow the exact repositioning of the specimen at the time of cementation. The specimens were ultrasonically cleaned in ultrapure water for 10 minutes. After cleaning, they were immersed in ultrapure water at 37°C for 24 hours to allow the materials to polymerize completely.

Twenty specimens of each interim cement were prepared in the same way as described for the interim resins for the fluorescence measurements (Table 1). The resin-based cements were light polymerized for 10 seconds. An LED light-polymerization unit (LED-5; Kondortech) with an irradiance of 1100 mW/cm<sup>2</sup> was used. The irradiance was evaluated using a radiometer (L.E.D, Demetron; Kerr Corp).



**Figure 1.** Experiment design.

For the control, a transparent liquid (PEG 400; Lab-Synth) with a refractive index close to that of the dentin (1.655) was used as an optical contact between the restorative material and dentin. For the experimental groups, 2 conventional and 2 resin-based interim types of cement were tested (Table 1). The cements were directly applied to the dentin surfaces, and the resin disks were placed over them. To standardize the thickness of the cement film, a load of 9.8 N<sup>16</sup> was applied to the assembly for 20 seconds.<sup>10</sup> For resin-based cements, each side of the assembly was polymerized for 10 seconds. The specimens were immersed in ultrapure water at 37°C for 24 hours before measurement of the  $\Delta E_{00}$ , TP, and fluorescence.

Because of the chemical interaction between the resin-based cements and interim resins, the surfaces of

the interim resins disks were isolated with a thin layer of petroleum jelly to facilitate removal after cementation. After each cementation and optical properties analysis, the assemblies were separated, cleaned, and luted with another material. The same interim restorations and dentin specimens were used in all groups.

The cements were randomly used in each combination of dentin and resin. The randomization was performed using a random list generated from a website ([www.sealedenvelope.com](http://www.sealedenvelope.com); function “Create a randomization list”) with 5 treatment groups, 5 block sizes, and a list length of 100 for all comparison groups. Two lists were created, 1 for each type of resin.

The color difference evaluation was performed separately for each interim resin with a reflectance

spectrophotometer (CM-2600d; Konica Minolta). Before cementation, the color coordinates of the control group for each assembly were assessed. The device was adjusted to use the D65 standard illuminant with 100% UV light with the specular component included. The observer angle was set at 2 degrees, and the device was adjusted to a small reading area of 3 mm. Three consecutive measurements were carried out to obtain an average of L\* a\* b\* chromatic coordinates. After that, the color of the experimental groups was evaluated.

The color of each combination of dentin, cement, and resin was measured over a white (L\*: 84.95; a\*: -0.38; b\*: 2.93) standard background (Ceram) and subsequently over a black (L\*: 2.58; a\*: -0.15; b\*: -0.24) background (Ceram). Optical contact between the specimen and the backgrounds was improved by using an interfacing layer of a PEG 400 solution.<sup>17</sup> Using the data obtained over the white background, the total color difference was calculated comparing the color of the control group with the color of the different experimental groups for each combination of dentin-resin disks. The CIEDE2000 color difference ( $\Delta E_{00}$ ) was calculated by the method of Commission Internationale de l'Eclairage where  $K_L$ ,  $K_C$  and  $K_H$  were set to 1.0.

The clinical thresholds described by Paravina et al<sup>18</sup> were considered:  $\Delta E_{00}$  of 0.8 for the perceptibility threshold and  $\Delta E_{00}$  of 1.8 for the acceptability threshold. These clinical thresholds were adopted in the present study and are used for the ISO/TR 28642 standard.<sup>19</sup>

The TP<sup>20-22</sup> was determined by calculating the color difference between the L\*, a\*, and b\* coordinates obtained over the black and white backgrounds for each assembly using the following formula:

$$TP = \left[ (L_b^* - L_w^*)^2 + (a_b^* - a_w^*)^2 + (b_b^* - b_w^*)^2 \right]^{1/2},$$

where the subscript b refers to the color coordinates of specimens over the black background and the subscript w refers to those measurements over the white background.

Fluorescence was measured using a spectrofluorophotometer (RF-5301 PC; Shimadzu Corp) with an excitation wavelength of 365 nm. The emission spectrum (400 to 600 nm) was obtained, and the value of the emission peak in fluorescence units (FU) and wavelength were recorded by using the "peak pick" tool of a specific software program (RFPC; Shimadzu Corp). For the enamel/dentin assembly, a drop of PEG 400 was used between the substrates. Any excess of liquid was removed, and the reading was made. The intrinsic fluorescence of each interim cement and the pure acrylic and bis-acrylic resins was also measured.

The repeatability and reproducibility of each instrument were assessed by measuring each specimen (n=5) 3 consecutive times and averaged. The same specimens were measured again after repositioning, and the

**Table 2.** Mean  $\pm$  standard deviation of  $\Delta E_{00}$  for each group

Interim Cement	Interim Resin	
	Acrylic Resin	Bis-Acrylic Resin
Bifix Temp	0.87 $\pm$ 0.48	0.66 $\pm$ 0.18
ClearTemp LC	1.29 $\pm$ 0.63	0.89 $\pm$ 0.57
TempCem NE	2.22 $\pm$ 0.64	1.46 $\pm$ 0.50
Provicol	1.74 $\pm$ 0.57	1.02 $\pm$ 0.39

**Table 3.** Results of 2-way ANOVA for  $\Delta E_{00}$

Effect	SS	df	MS	F	P
Intercept	260.10	1	260.10	961.30	<.001
Interim cement	24.88	3	8.29	30.65	<.001
Interim resin	10.95	1	10.95	40.46	<.001
Interim cement $\times$ Interim resin	2.07	3	0.69	2.55	.062

MS, mean square value; SS, sum of squares value.

reproducibility was calculated. For the spectrophotometer, the values of repeatability was  $\Delta E_{00} = (0.32 \pm 0.03)$  and reproducibility was  $\Delta E_{00} = (0.34 \pm 0.14)$ . For spectrofluorophotometer, the discrepancy values were  $0.94 \pm 0.51$  FU and  $7.95 \pm 5.36$  FU.

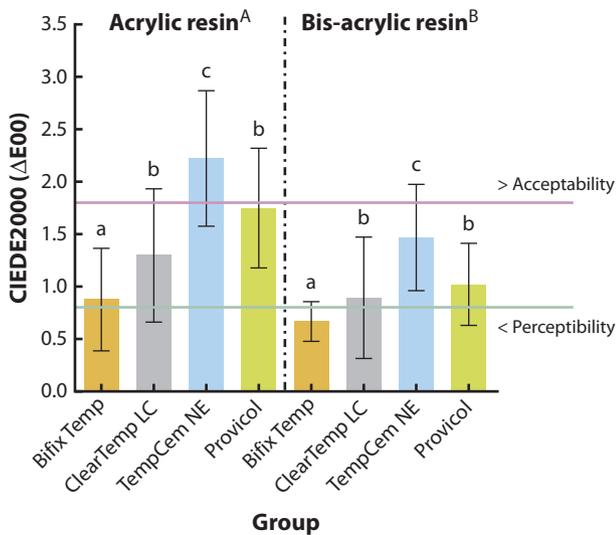
The normality of the data was analyzed using the Kolmogorov-Smirnov test. As all groups showed normal distribution ( $P > .05$ ), color difference and TP data were analyzed with 2-way ANOVA. Fluorescence was assessed with 1-way ANOVA. Subsequently, the Tukey test for multiple comparisons was performed ( $\alpha = .05$ ).

## RESULTS

The means and standard deviations for color differences are presented in Table 2. The 2-way ANOVA showed significant differences among interim resins ( $P < .001$ ) and among the cements ( $P < .001$ ) for  $\Delta E_{00}$  (Table 3). Figure 2 shows the results of the Tukey test. Acrylic resin showed higher color difference than bis-acrylic resin. For both interim resins, the cement Bifix Temp had significantly the lowest  $\Delta E_{00}$  values. The highest  $\Delta E_{00}$  values were observed for TempCem NE.

The means and standard deviations of TP are presented in Table 4. The 2-way ANOVA showed significant differences of TP among the different types of cement (Table 5). The lowest translucency values were measured for TempCem NE, followed by Provicol, ClearTemp LC, Bifix Temp, and control group ( $P < .001$ ), without significant differences among the interim resin-based cements (Fig. 3). The Bifix Temp associated with acrylic resin showed significantly higher translucency values than with bis-acrylic resin.

For fluorescence, the values obtained from the dentin/cement/resin assemblies, as well as the intrinsic fluorescence of each type of cement, interim materials, and natural teeth, were compared. The means and standard deviations are presented in Table 6. One-way ANOVA showed significant differences for



**Figure 2.** Means of color difference ( $\Delta E_{00}$ ) and results of Tukey test. Perceptibility, 0.8  $\Delta E_{00}$  units.<sup>20</sup> Acceptability, 1.8  $\Delta E_{00}$  units.<sup>20</sup> Different uppercase letters represent significant differences between interim resins. Different lowercase letters represent significant differences among interim cements.

**Table 4.** Mean  $\pm$ standard deviation translucency parameter values for each group

Interim Cement	Interim Resin	
	Acrylic Resin	Bis-Acrylic Resin
PEG 400 (control group)	12.88 $\pm$ 2.93	13.45 $\pm$ 2.33
Bifix Temp	9.17 $\pm$ 1.90	7.11 $\pm$ 1.86
ClearTemp LC	7.52 $\pm$ 1.77	8.32 $\pm$ 2.13
TempCem NE	2.15 $\pm$ 0.61	3.23 $\pm$ 1.31
Provicol	5.71 $\pm$ 1.17	4.02 $\pm$ 1.34

**Table 5.** Two-way ANOVA for translucency parameter

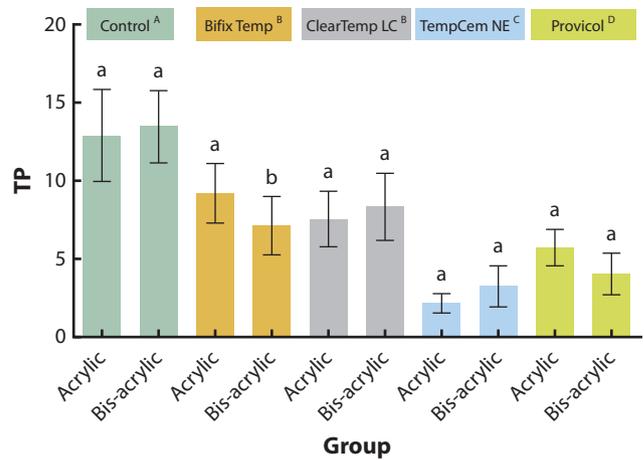
Effect	SS	df	MS	F	P
Intercept	10 834.70	1	10 834.70	3171.64	<.001
Interim cement	2504.40	4	626.10	183.27	<.001
Interim resin	3.42	1	3.42	1.00	.318
Interim cement $\times$ Interim resin	88.79	4	22.20	6.49	<.001

MS, mean square value; SS, sum of squares value.

fluorescence (df=16, F=825.08,  $P<.001$ ). The Tukey test showed that the intrinsic fluorescence of ClearTemp LC was significantly higher than that of the natural tooth, and its associations with the interim resins were significantly greater than that of the natural tooth (Fig. 4). Among the interim cements, Bifix Temp and TempCem NE were able to yield fluorescence similar to that of the natural tooth for both interim resins. A similar result was found for bis-acrylic resin combined with Provicol.

### DISCUSSION

The results of this study showed that the color, translucency, and fluorescence of cemented interim



**Figure 3.** Means of TP and results of Tukey test. Different uppercase letters represent significant differences for factor interim cement. Different lowercase letters represent significant differences between interim resins. TP, translucency parameter.

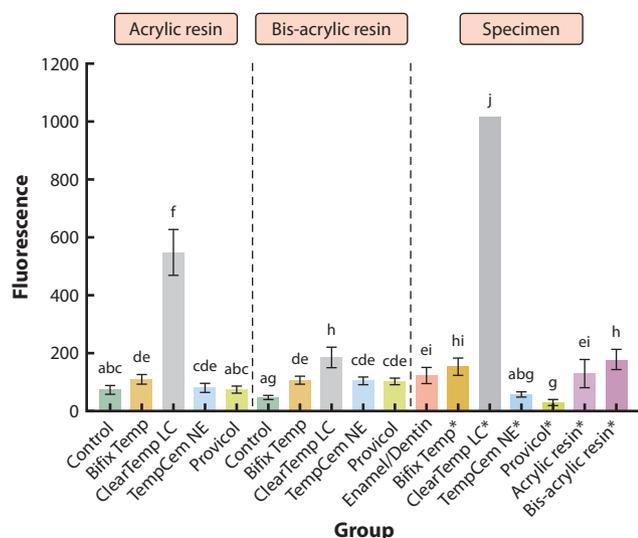
**Table 6.** Mean  $\pm$ standard deviation fluorescence values (FU)

Groups/Material/ Substrate	Assemblies		
	Acrylic Resin	Bis-Acrylic Resin	Specimen
PEG 400 (control group)	73.29 $\pm$ 15.29	47.33 $\pm$ 6.96	—
Bifix Temp	109.87 $\pm$ 16.96	106.88 $\pm$ 13.89	153.56 $\pm$ 30.07
ClearTemp LC	548.09 $\pm$ 79.25	185.74 $\pm$ 35.75	1015.84 $\pm$ 0.12
TempCem NE	80.82 $\pm$ 15.33	104.71 $\pm$ 13.14	57.80 $\pm$ 8.92
Provicol	73.80 $\pm$ 12.03	102.50 $\pm$ 11.72	29.96 $\pm$ 10.41
Acrylic resin	—	—	129.60 $\pm$ 49.56
Bis-acrylic resin	—	—	178.13 $\pm$ 35.09
Enamel/dentin	—	—	124.88 $\pm$ 29.02

restorations are influenced by the type of cement and interim resin; thus, the null hypotheses were rejected.

According to the results of this study,  $\Delta E_{00}$  values were significantly influenced by the interim material and the interim cement (Table 3). Comparing the interim resin materials, the  $\Delta E_{00}$  values for the acrylic resin were higher than those for the bis-acrylic resin, which means that the color of cement had a greater influence on the acrylic than on the bis-acrylic resin (Fig. 2). This may be related to the presence of filler particles in the bis-acrylic resin, which may help mask the color of the material under it.

All evaluated groups (except for the association of acrylic resin with TempCem NE) showed clinically acceptable values ( $\Delta E_{00}<1.8$ ). TempCem NE is more opaque than the other cements tested, making it more effective in masking discolored substrate. However, in areas of high esthetic demand, its opacity could reduce the esthetic result. Only the association of acrylic resin with Bifix Temp showed the  $\Delta E$  value to be under the perceptibility threshold ( $\Delta E_{00}<0.8$ ), suggesting that a better esthetic result can be obtained with this cement.



**Figure 4.** Means of fluorescence and results of Tukey test. Different letters represent significant differences among groups. Asterisk symbol (\*) represents pure specimen of materials.

The TP of a material refers to its ability to mask the color difference over 2 achromatic backgrounds (black and white).<sup>20</sup> The difference in translucency is related to different absorption and light-scattering capacities.<sup>21</sup> The more translucent the specimen, the higher the proportion of light transmitted through it and absorbed by the black background.<sup>22</sup> Consequently, light is not reflected back, and the masking ability of the material is reduced. The present study showed that interim resin-based cements presented higher TP values (Fig. 3). Thus, the indication for using these cements should be restricted because they do not mask discolored substrates. Furthermore, the association of Bifix Temp with acrylic resin resulted in a higher TP than the association with bis-acrylic resin. Polymethylmethacrylate-based resins without filler particles in their composition have a more homogeneous internal structure, without scattering or light reflection. This may lead to increased translucency, allowing light to pass easily and, consequently, allowing the cement and the tooth substrate to be observed more clearly. For the bis-acrylic resin, translucency is related to multiple reflections and refractions occurring at the interface between the resin matrix and the filler particles, which is influenced by the difference in the refractive index of both.<sup>23</sup>

Another important optical property of dental tissues is fluorescence.<sup>13</sup> Natural teeth emit a strong blue fluorescence under UV light.<sup>11</sup> Under these conditions, the restorations may appear lighter or darker relative to the adjacent teeth.<sup>15</sup> In natural teeth, the fluorescence of the enamel is attributed mainly to its organic components, which correspond to 2% of its total composition, and is directly proportional to its thickness.<sup>24</sup> Thus, the higher the thickness of the substrate, the higher the

fluorescence.<sup>25</sup> However, this optical property is mainly determined by dentin because of the higher amount of amino acids, such as tryptophan, present in the collagen substrate.<sup>24</sup> In the present study, the dentin specimens used throughout the experiment were also evaluated together with the enamel to determine the natural fluorescence of the teeth. Differences also occur concerning the fluorescence of the materials. For better understanding, the intrinsic fluorescence of the interim cements and interim resins were also evaluated. These measurements revealed that the Bifix Temp presents fluorescence similar to that produced by acrylic and bis-acrylic resins (Fig. 4). However, ClearTemp LC showed fluorescence about 10 times higher than that of the other materials. According to the manufacturer information, the high fluorescence of this material is intended to aid in the detection and complete removal of interim cement before definitive cementation under illumination with a UV light source.

Bifix Temp and acrylic resin, as well as the combination of these materials, showed fluorescence values similar to those of the natural tooth (Fig. 4). The results of this study suggest that this combination may be used without significantly altering fluorescence and color. However, the translucency of these materials can allow more light to enter and increase scattering. Thus, the underlying color can have a significant impact on the final result.

The bis-acrylic resin is intrinsically more fluorescent than natural tooth and can be influenced by the interim cement (Fig. 4). This may be particularly important when the interim cement presents lower fluorescence. The results showed that the conventional cements with low intrinsic fluorescence apparently changed the total fluorescence. Thus, the association with TempCem NE and Provicol was able to yield fluorescence similar to that of the natural tooth. A similar result was found for bis-acrylic resin combined with Bifix Temp. Furthermore, the fluorescence of ClearTemp LC was reduced after cementation. This suggests that the resin must have been able to reduce the penetration of incident UV light or the output of the blue light generated by the cement layer to the external surface. However, the esthetics of restorations cemented with this cement, which is intrinsically very fluorescent, can be compromised.

The optical properties of interim restorative materials require additional studies because the final esthetic appearance results from a combination of factors that are not restricted to those evaluated in this study. Also, other variables inherent to the material and clinical conditions may promote changes in esthetics. Thus, the results of this in vitro study should be interpreted cautiously. The thickness of dentin/enamel specimens may not replicate the optical effects of the natural tooth and is a limitation of the present study. Another limitation is that discolored

substrates were not investigated and should therefore be considered in future research.

## CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The color, translucency, and final fluorescence of the restorations were influenced by the type of cement.
2. Interim resin-based cements present less color difference and greater translucency.
3. High-fluorescence resin-based cement may interfere with the final esthetic result of thin interim restorations.

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