Effects of Photodynamic Therapy on the Adhesive Interface of Fiber Posts Cementation Protocols

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Abstract

Introduction: The aim of this study was to evaluate the effects of photodynamic therapy (PDT) on the bond strength and dentinal penetrability of cementation protocols using conventional resin cement (Relyx ARC; 3M ESPE, St Paul, MN) or self-adhesive (Relyx U200, 3M ESPE) after the glass fiber post cementation. **Methods:** Forty human canine roots were endodontically treated and prepared for a fiber post. The roots were divided into 4 groups according to the cementation protocol and PDT use: conventional cement (CC), Relyx ARC; self-adhesive cement (SAC), Relyx U200 cement; PDT/CC, PDT + Relyx ARC; and PDT/SAC, PDT + Relyx U200. After cementation of the fiber posts, the roots were cross sectioned, and then specimens from the cervical, middle, and apical thirds of the prosthetic space were obtained. The specimens were submitted to the pushout test and dentinal penetration evaluation of the cementation protocol using laser confocal microscopy. **Results:** PDT/CC presented the lowest bond strength to root dentin in the cervical third ($P < .05$). In the middle and apical thirds, all groups presented a similar bond strength ($P > .05$). PDT/CC presented the lowest dentinal penetration of the adhesive system in the cervical and apical thirds ($P < .05$). **Conclusions:** PDT presented negative effects on the bond strength to dentin in the cervical third after cementation using Relyx ARC and on the dentinal penetrability of the etch-and-rinse adhesive system in the cervical and apical thirds of the prosthetic space. *(J Endod 2018;44:173–178)*

Key Words

Bond strength, fiber posts, photodynamic therapy, pushout bond strength, self-adhesive cement

Significance

Microbial contamination is a common clinical situation during post space preparation that compromises the success of endodontic treatment. Antisepsis protocols have been recommended; however, it is still unclear whether these protocols affect post adhesion.

Intracanal preparation of the prosthetic space for a fiber post requires a partial removal of root canal obturation. During this procedure, local contamination may occur, which compromises the success of endodontic and/or restorative treatments (1, 2). Sodium hypochlorite and chlorhexidine digluconate have been recommended for prosthetic space irrigation, but they have shown negative effects on the bond strength of the resin cements to root dentin (3–5).

Free radicals participate in the polymerization process of resinous compounds inducing chemical reactions in the methacrylate structure (6). Thus, the degree of conversion and the adhesion of resinous materials to the dentin are compromised by the substances that interact with these free radicals, such as sodium hypochlorite, which degrades in sodium hydroxide and hypochlorous acid and, consequently, leads to singlet oxygen formation (7–9). Moreover, the presence of oxygen can also work as a barrier in the adhesive interface, which hampers hybrid layer formation in dentin (10).

Because sodium hypochlorite may cause undesirable effects, other alternatives have been sought to perform prosthetic space antisepsis. Henceforth, photodynamic therapy (PDT) with specific photosensitizers, such as 0.005% or 0.01% methylene blue, has been an interesting option (11) because of its satisfactory antimicrobial activity in contaminated root canals (12).

The mechanism of action of PDT occurs when a photosensitizing substance absorbs the photons from the irradiation source and their electrons enter an excitation state. Then, the energy is transferred to a specific substrate, forming reactive oxygen species (ROS) (mainly singlet oxygen), which irreversibly oxidize the cellular components causing bacterial death (11, 13, 14). However, it is still unknown whether the free radicals from the ROS release affect the adhesive interface between the dentin and fiber post cement after different cementation protocols, similar to the decontamination protocols using sodium hypochlorite.

Therefore, the aim of this study was to evaluate the effects of PDT using 0.005% methylene blue in the intracanal prosthetic space on the bond strength and intradentinal penetrability using conventional (Relyx ARC; 3M ESPE, St Paul, MN) or self-adhesive (Relyx U200, 3M ESPE) resin cements in different root thirds after the fiber post cemen-

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TABLE 1. Materials, Manufacturers, Origin, and Chemical Composition of Materials and Groups

Material	Composition	Groups
Relyx ARC (3M ESPE, St Paul, MN)	Paste A: BisGMA, TEGDMA, zirconia silica, pigments, amine, and photoinitiator system Paste B: BisGMA, TEGDMA, zirconia silica, benzoyl peroxide	Groups 1 and 3
Relyx U200 (3M ESPE)	Base paste: glass powder treated silane, 2-propenoic acid, 2-metil 1,1′-[1-(hydroxymetil)-1,2- ethanodlyl] ester, triethylene dimethylacrylate with silane, glass fiber, sodium persulfate, and t-butyl per-3,5,5–trimethylhexanoate Catalyst paste: silane-treated glass powder, substituted dimethacrylate, silanated silica, sodium p-toluene sulfonate, 1-benzyl-5-phenyl-baric acid, calcium salts, 1,12-dodecane dimethacrylate, calcium hydroxide and titanium dioxide	Groups 2 and 4
Adper Scotchbond Multipurpose (3M ESPE)	Primer: 2-hydroxyethyl methacrylate in aqueous solution (HEMA) and polyalkenoic acid copolymer Adhesive: bisphenol diglycidyl dimethacrylate solution (Bis-GMA), 2-hydroxyethyl methacrylate (HEMA), and Camphorquinone	Groups 1 and 3

tation protocols. The null hypothesis was that PDT does not affect the adhesion and the dentinal penetration of fiber post cements.

Materials and Methods

The study was approved by the Research Ethics Committee of Araraquara School of Dentistry (São Paulo State University-Unesp) (1.603.859). Forty human canines with a similar root anatomy and the absence of structural alterations were selected and kept in 0.1% thymol solution at 4°C.

The dental crowns were removed about 15 mm from the root apex. Then, chemical-mechanical preparation and root canal obturation were performed according to Aranda-Garcia et al (15). After vertical condensation obturation, the cervical opening was sealed using temporary cement (Coltosol; Coltene, Rio de Janeiro, Brazil), and the roots were stored under 100% relative humidity at 37°C for 7 days.

The preparation of the intracanal prosthetic space was performed using a #2 bur (White Post DC System; FGM, Joinville, SC, Brazil) with an 11-mm length. Then, it was irrigated using 10 mL distilled water and dried with absorbent paper points. The specimens were randomly divided into 4 groups (n = 10) according to the cementation protocol and PDT application in the prosthetic space: conventional cement (CC), Relyx ARC; self-adhesive cement (SAC), Relyx U200; PDT/CC, PDT + Relyx ARC; and PDT/SAC, PDT + Relyx U200.

The fiber post surface was cleansed using 95% ethanol and etched with 37% phosphoric acid (Power Etching; BM4, Palhoça, SC, Brazil) for 1 minute, and then silane (Prosil, FGM) and dentin adhesive (Adper Scotchbond Multiuso Plus, 3M ESPE) were applied throughout its length. Afterward, the whole set was light cured for 60 seconds (Bluephase; Ivoclar Vivadent, Barueri, SP, Brazil).

PDT was performed in the PDT/CC and PDT/SAC groups. Initially, the prosthetic space was filled with 1000 μL 0.005% methylene blue (Chimiolux; DMC, São Carlos, SP, Brazil), and the root cervical face was covered with laminated paper and left untouched for 5 minutes. After that, an optical fiber (Twin Flex Evolution; MMO Opto-Electronic Equipment, São Carlos, SP, Brazil) was inserted into the entire prosthetic space in a static position, and the prosthetic space was irradiated for 30 seconds using a laser emission source (Twin Flex Evolution) with an output power of 30 J/cm^2.

Afterward, methylene blue was aspirated, and the prosthetic space was irrigated with 3 mL saline solution and dried with absorbent paper points. Before fiber post cementation, 0.01% (by mass) Rhodamine B isothiocyanate was added to the primer of the adhesive system (Adper Scotchbond Multiuso Plus) and used in the CC and PDT/CC groups. Rhodamine B isothiocyanate was also added to the cements and used in the SAC and PDT/SAC groups. All specimens were subjected to laser confocal microscopic evaluation.

Specimens in the CC and PDT/CC groups were acid etched (Power Etching) for 15 seconds, irrigated with distilled water for 30 seconds, and dried with absorbent paper points. The adhesive system (Adper Scotchbond Multiuso Plus) was applied throughout the prosthetic space and light cured for 20 seconds (Bluephase).

The cements were handled according to the manufacturers' recommendations and are described in Table 1. Immediately after the cementation of #2 (FGM) fiber posts, the roots were vertically centralized inside a polyvinyl chloride matrix (16.5 diameter × 15.0-mm length) and checked using a parallelogram (BioArt B2, São Carlos, SP, Brazil). The matrices were filled with polyester resin (Maxi Rubber, Diadema, SP, Brazil), leaving 1.0 mm of the root cervical outside the inclusion. The whole set was left undisturbed for 24 hours. Then, the

TABLE 2. Mean and Standard Deviation of Bond Strength (in MPa) in the Root Thirds of the Prosthetic Space according to Photodynamic Therapy (PDT) Use in the Prosthetic Space

Groups	Cervical	Middle	Apical
Group 1: Relyx ARC	4.21 ± 1.06[a]	3.56 ± 1.13[a]	3.96 ± 1.96[a]
Group 2: Relyx U200	6.09 ± 1.66[a]	4.38 ± 2.22[a]	3.51 ± 1.54[a]
Group 3: PDT + Relyx ARC	2.45 ± 0.78[b]	3.27 ± 1.56[a]	3.65 ± 1.52[a]
Group 4: PDT + Relyx U200	4.55 ± 1.57[a]	4.71 ± 1.06[a]	4.66 ± 1.37[a]

Different superscript letters in the same column indicate significant differences ($P < .05$).

TABLE 3. Mean and Standard Deviation of the Penetration (%) of Fiber Post Cement in Root Dentin in All Thirds of the Prosthetic Space according to the Cementation Protocol and Photodynamic Therapy (PDT) Use

Groups	Cervical	Middle	Apical
Group 1: Relyx ARC	34.85 ± 6.60[a]	39.14 ± 19.80[a]	16.01 ± 1.46[a]
Group 2: Relyx U200	42.89 ± 12.44[a]	49.29 ± 19.33[a]	19.56 ± 5.18[a]
Group 3: PDT + Relyx ARC	11.82 ± 3.02[b]	26.52 ± 16.08[a]	6.36 ± 3.18[b]
Group 4: PDT + Relyx U200	41.28 ± 16.10[a]	41.76 ± 23.78[a]	18.19 ± 3.21[a]

Different superscript letters in the same column indicate significant differences ($P < .05$).

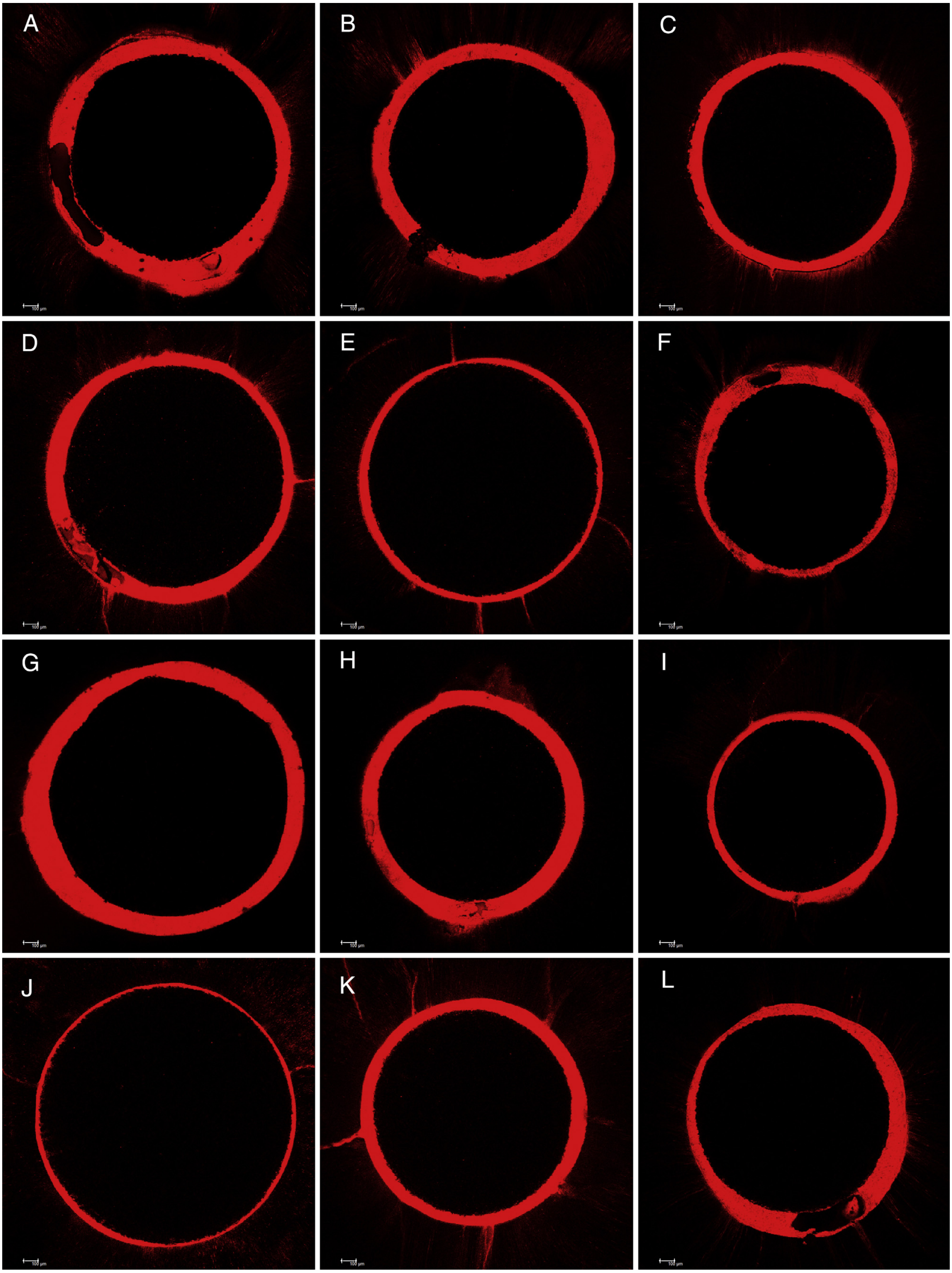

Figure 1. Representative images of the dentinal penetrability in the groups evaluated. (*A–C*) CC, cervical, middle, and apical thirds, respectively. (*D–F*) SAC, cervical, middle, and apical thirds, respectively. (*G–I*) PDT/CC, cervical, middle and apical thirds, respectively. (*J–L*) PDT/SAC, cervical, middle, and apical thirds, respectively. CC, Relyx ARC; SAC, Relyx U200; PDT/CC, PDT + Relyx ARC; and PDT/SAC, PDT + Relyx U200.

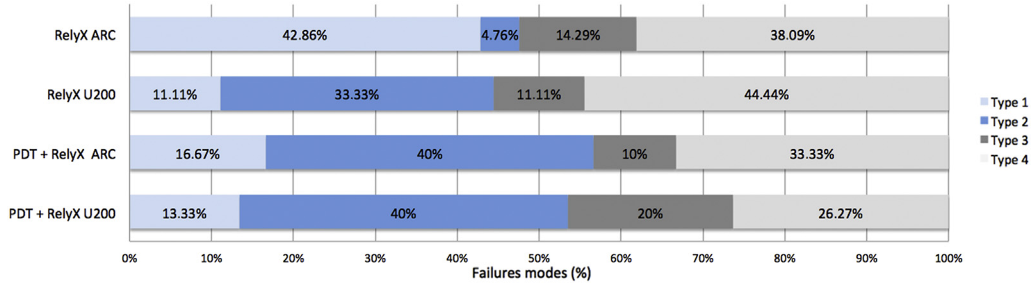

Figure 2. Distribution of the failure mode in each group.

specimens were removed from the matrices and sectioned perpendicular to their long axis with a diamond disk using a hard tissue cutting machine (Isomet; Buehler Ltd, Lake Bluff, IL) under running water cooling. Three sections were performed with 2.0 mm ± 0.1 mm thickness from the apical, middle, and cervical thirds of the prosthetic space. The cervical, medial, and apical radicular sections were carried out from 1.0 mm, 5.0 mm, and 8.0 mm from the root cervical face, respectively. The section irregularities were removed using #1200 (Norton, São Paulo, SP, Brazil) sandpaper.

The specimens of each root third were submitted to a pushout test using an electromechanical test machine (EMIC, São José dos Pinhais, PR, Brazil) at 0.5-mm/min speed using a 5-kN load cell until complete displacement of all root canal walls. The force required for the displacement to occur was obtained in newtons, and it was transformed into bond strength (MPa) according to Magro et al (16). Subsequently, each specimen was assessed using a stereomicroscope at 20× magnification to determine the failure mode. The failure mode was classified as type 1 (adhesive) when it occurred between the fiber post and the cement, type 2 (adhesive) when it occurred between the dentin and the cement, type 3 (cohesive) when it occurred within the cement, and type 4 (mixed) when both types of failure were combined, according to Elnaghy (17).

The sections were analyzed using a laser confocal microscope at 100× magnification to determine the root canal perimeter with the material penetration within the dentinal tubules. The images were evaluated using ImageJ software (National Institutes of Health, Bethesda, MD). The perimeter of the root canal and cement penetration in dentin were measured, and the percentage of material penetration in the dentinal tubules was obtained.

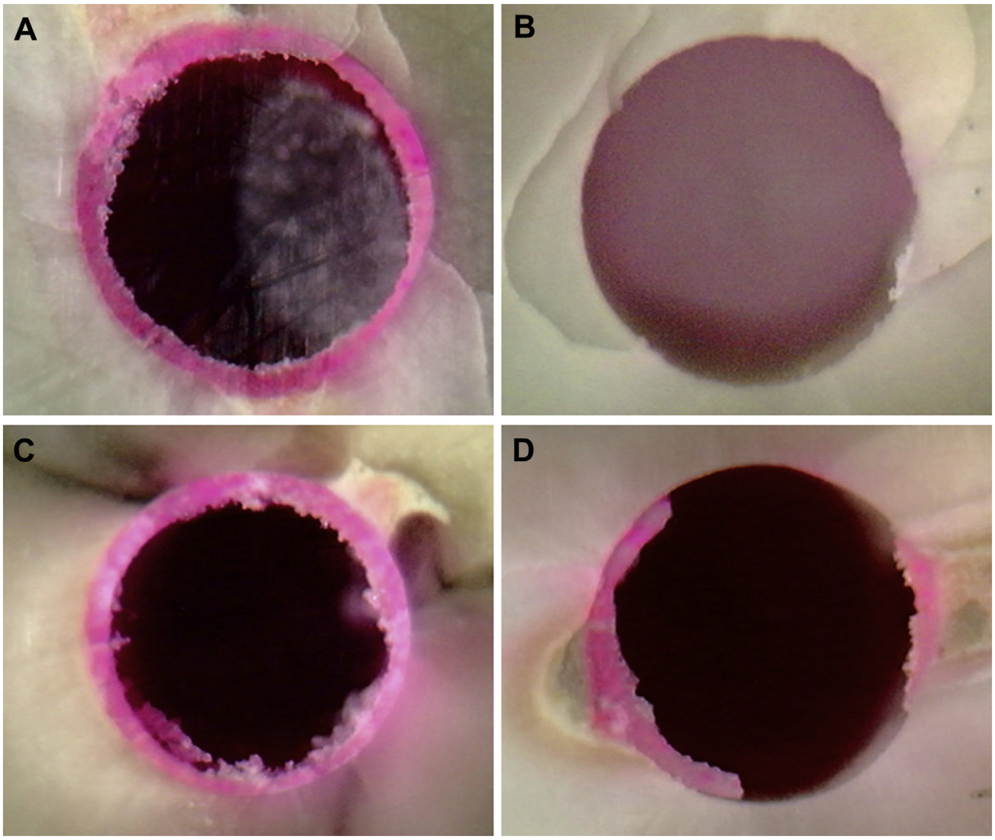

Figure 3. Failure mode representative images. (*A*) Type 1, adhesive failure between the post and luting material; (*B*) type 2, adhesive failure between the dentin and the luting material; (*C*) type 3, cohesive failure within the luting material; and (*D*) type 4, mixed failure.

Statistical Analysis

Data were submitted to analysis of variance and Tukey tests at a 5% significance level.

Results

Regarding the bond strength of the fiber post cements to root dentin, all groups presented similar results in the middle and apical thirds of the prosthetic space ($P > .05$). The PDT/CC group was the only group that presented the lowest value in the cervical third ($P < .05$). Table 2 shows the mean and standard deviation of bond strength (in MPa) of each third according to PDT use in the prosthetic space.

In relation to the dentinal penetration of the fiber post cementation protocols, all groups presented similar results in the middle third ($P > .05$). In the cervical and apical thirds, the PDT/CC group presented the lowest dentinal penetration ($P < .05$). Table 3 shows the mean and standard deviation of the dentinal penetration (%) of the fiber post cementation protocols in all thirds of the prosthetic space according to the cementation protocol and PDT use. Figure 1*A–L* shows the dentinal penetration pattern of the groups.

Regarding the failure mode, the PDT/CC and PDT/SAC groups presented a higher incidence of type 2 failure. The CC group presented a higher incidence of type 1 failure. The SAC group presented a higher incidence of type 4. Figure 2 displays the failure mode distribution and Figure 3*A–D* representative images of the failure mode.

Discussion

PDT negatively affected the bond strength of the Relyx ARC system to the cervical third of the prosthetic space. In addition, the dentinal penetration of this cementation system was compromised in the cervical and apical thirds of the intracanal prosthetic space. Thus, the null hypothesis was rejected.

Oxygen affects the adhesive interface of resinous compounds in dentin (18) due to the competition of free radicals responsible for the methacrylates polymerization reactions. Moreover, the accumulation of ROS in dentin hampers hybrid layer formation (19). Because PDT releases ROS, it is assumed that it also affects the adhesion of fiber post cementation protocols (13).

However, bond strength reduction was only observed in the cervical third of the prosthetic space after conventional cement (Relyx ARC) use. Before resin cement use, the etch-and-rinse (Adper Scotchbond Multi-Purpose Plus) adhesive system was applied; therefore, it is possible that products from the photoactivation of 1% methylene blue, mainly the singlet oxygen, competed with the free radicals, which reacts in the chemical reaction of camphorquinone and aliphatic amines. It negatively affected the polymerization and adhesion of the adhesive system in dentin (20, 21).

Furthermore, Garcez et al (11) have reported that light distribution and oxygen formation were uniform when the optical fiber was used in spiral movements for approximately 10 minutes. These steps may have influenced the results because this study used an optical fiber in a static position for 30 seconds; consequently, the irradiation may have been concentrated mainly in the radicular cervical third.

PDT did not present an effect on the interface when Relyx U200 cement was used. The mechanism of adhesion of this cement is mainly based on the chemical interaction between acidic monomers and hydroxyapatite, and it does not only depend on mechanical microretention in root dentin (6), thus, the ROS interference on the adhesion of this cement to root dentin was null in accordance with Barreto et al (22).

Laser confocal microscopy has been used to evaluate the material's penetrability and adaptation in root dentin (23). The PDT/CC group presented lower dentinal penetrability in the cervical and apical thirds. It can be associated with the high concentration of oxygen, which worked as a mechanical barrier and hampered the penetration of the adhesive system in the dentinal tubules (10). Moreover, Grandini et al (24) have observed that higher incidences of gaps and cementation failures occurred in the apical third of the prosthetic space, similar to the specimens in the PDT/CC group, because of the presence of oxygen.

The PDT/CC and PDT/SAC groups presented the highest incidence of failure mode between the root dentin and the cementation protocol because of ROS release in the adhesive interface. On the other hand, the protocol using the etch-and-rinse adhesive system is considered as a reference standard in fiber post cementation, which favored type 2 failure mode occurrence (6, 25). The SAC group showed a mixed failure mode, which agreed with previous studies that used this cement (6, 26, 27). Failure mode analysis shows where the adhesive failure occurred. The present study showed PDT with methylene blue favored the failure mode between the dentin substrate and the Relyx ARC luting system in the cervical third, suggesting that PDT-generated ROS may affect dentin hybridization.

The results showed that the methods that have been used in antisepsis of fiber post space can affect the adhesion of the luting systems to root dentin. Therefore, it is relevant to use materials, such as rubber dam isolation, in order to avoid contamination during post space preparation.

Despite PDT prosthetic space antisepsis performance, it releases ROS, mainly singlet oxygen. The present study has shown that PDT affects fiber post cementation protocols; however, further studies should be performed to evaluate the interaction of PDT with other photosensitizing substances and new protocols for fiber post cementation, such as ionomer cements (28).

In conclusion, PDT with 0.005% methylene blue presented negative effects on the bond strength of the cementation protocol using conventional cement (Relyx ARC) in the cervical third and on the dentinal penetrability of the etch-and-rinse adhesive system in the cervical and apical thirds of the prosthetic space.

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The authors deny any conflicts of interest related to this study.

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CORRIGENDUM

Corrigendum to 'Outcome of Direct Pulp Capping with Mineral Trioxide Aggregate: A Prospective Study' [Journal of Endodontics 41 (2015) 1026–1031]

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The authors would like to correct the title of the article published in the July 2015 issue of *Journal of Endodontics*, "Outcome of Direct Pulp Capping with Mineral Trioxide Aggregate: A Prospective Study." The title should be "Outcome of Direct Pulp Capping with Mineral Trioxide Aggregate," as the words "Prospective Study" are misleading.

The authors would like to apologize for any inconvenience caused.