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The Effect of In-office in Combination with Intracoronal Bleaching on Enamel and Dentin Bond Strength and Dentin Morphology

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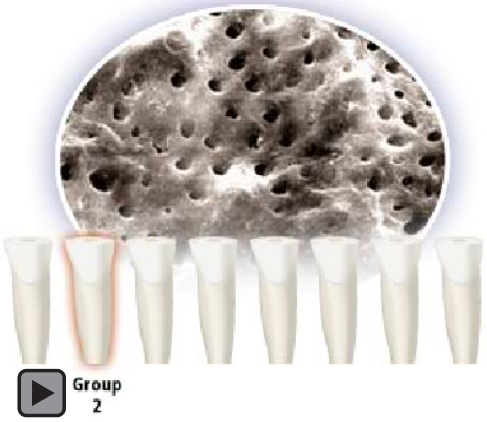

Abstract

Aim: The aim of this study was to evaluate *in vitro* effects of the combination of in-office and intracoronal bleaching on enamel and dentin bond strength and on dentin morphology.

Methods and Materials: Bleaching treatment was performed on 128 bovine teeth for three weeks. Intracoronal bleaching was performed in groups G1 to G3, and in the other groups a combination of in-office and intracoronal bleaching was performed. The following agents and materials were used (n=16): G1- sodium perborate and water (SP); G2- 37% carbamide peroxide (CP); G3- 35% hydrogen peroxide (HP); G4- HP + cotton pellet soaked in water (CPW); G5- HP + SP; G6- HP + CP; G7- HP + HP; and G8- CPW (control). Seven days after bleaching treatment the teeth were sectioned into two halves. One half of each tooth was ground to obtain a flat dentin surface. Dentin and enamel fragments were treated with a dentin/enamel resin adhesive. Resin composite was inserted in two increments and polymerized for 20 seconds. Following the restorative procedures, specimens were sectioned into beams with a rectangular cross-sectional area of approximately 1 mm^2. Microtensile testing was performed in a universal testing machine. Bond strengths (in MPa) were calculated and the data were submitted to an analysis of variance (ANOVA) and the Tukey test (α=0.05). For the scanning electron microscopy (SEM) observation, the exposed pulp chambers (n=5) were fixed, dehydrated, dried in a Critical Point dryer, and gold-sputter coated for analysis at standardized magnifications (500X, 1000X, and 2000X).

Results: None of the bleaching techniques reduced the enamel bond strength, the best results observed were with the intracoronal treatments with SP and HP. In dentin all bleaching techniques reduced the bond strength with the exception of the in-office HP application technique. The SEM results demonstrated similar dentin surfaces for the G1, G3, G6, and G7 groups with more open dentin tubules found than in the other groups.

Conclusion: None of the bleaching techniques tested reduced the bond strength of enamel, but they all reduced the bond strength of dentin with the exception of the group only treated with in-office bleaching using 35% HP. The worst bond strength results to dentin were observed in groups that received intracoronal bleaching with SP.

Keywords: Dental bleaching, adhesives, biomaterials, esthetic dentistry

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Introduction

Bleaching offers a conservative, simplified, and economical approach to changing the color of teeth and to improve the harmony of the smile.[1] In-office bleaching has been used to give patients a "jump start" in the bleaching process, to touch-up post-bleaching cases, and to function solely as a bleaching product.[2] This technique uses carbamide peroxide (CP) or hydrogen peroxide (HP) in concentrations from 30% to 37% with rubber dam or alternative barrier methods.[1,3]

The discoloration and loss of translucency of root filled nonvital teeth may also be effectively counteracted by treatment with chemical bleaching agents. Bleaching of endodontically treated teeth, with "walking bleaching", was described by Spasser (1961)[4] and modified by Nutting & Poe (1963).[5] Recently, this technique has been performed using sodium perborate and water (SP) or CP.[6]

When patients have their teeth bleached, they often become interested in veneers, replacing old restorations, diastema closures, or other esthetic procedures.[7] In addition, bleaching may be indicated before placing an esthetic composite resin restoration to obtain a more pleasing final shade for the patient.[8]

Subsequent to intracoronal bleaching endodontic access cavities are frequently restored with bonded composite resin. Ideally the enamel margin and the entire pulp chamber should be

sealed. Unless a glass–ionomer cement liner is used to cover the entire dentin surface it is essential to bond the resin to dentin and enamel to minimize marginal leakage to reduce percolation of bacteria and the effect of discoloring agents at the cavity margin.[9] Increased frequency of exposure to highly concentrated bleaching agents might enhance side effects,[10,11] such as pitting,[12] erosion,[13] porosity,[14] reduced fracture strength,[15] dissolution,[16,17] and effects similar to those of initial caries.[18]

Any change in the surface properties of both enamel and dentin after bleaching is likely to have an impact on the bonding effectiveness.[19,20,21] Teixeira et al.[22] observed a diminished bond strength to enamel in restorations made immediately after bleaching with sodium perborate in combination with HP. Whereas bleaching with CP or sodium perborate in combination with distilled water did not affect the bond strength when compared with the bond to non-bleached teeth.

More recently some manufacturers have indicated in-office vital tooth bleaching gels as aids for bleaching nonvital teeth by applying them on the facial face and inside the pulp chamber. These more concentrated bleaching agents release more HP and are able to potentate the bleaching reaction and amplify its effect. However, the increase in the concentration of free radicals in teeth could also cause side effects in more evident proportions.

Therefore, the purpose of this study was to determine the effect of combining intracoronal (sodium perborate and 37% CP) and in-office (35% HP) bleaching agents on the microtensile bond strength of an etch-and-rinse adhesive to enamel and dentin.

Methods and Materials

Preparation of Teeth

A total of 128 extracted bovine incisor teeth were stored in a 0.1% thymol solution and then used in this study. The teeth were rinsed under running water and all debris removed.

Each tooth was horizontally sectioned approximately 10 mm occlusally and 5 mm apically to the cementoenamel junction using a double-faced diamond disk (KG Sorensen, Barueri, Brazil) in a low-speed handpiece (Kavo do Brasil S.A., Joinville, Brazil). The pulp was removed with a dental probe, and the pulp chamber was enlarged to a standard size using a spherical #8 carbide bur (Metalúrgica Fava, Franco da Rocha, Brazil) in a high-speed handpiece.

A 3 mm-thick base material (Cimpat White, Septodont, Saint-Maur, France) was packed into the root canal to a level 2 mm below the cementoenamel junction to prevent apical leakage of the bleaching material during the walking bleaching technique.[17,23] The teeth were stored in distilled water at 37°C prior to and during bleaching treatment.

Bleaching Treatment

The specimens were randomly assigned into eight groups (n=16) according to the bleaching technique used as shown in Table 1. Group G8 (control) did not receive either in-office bleaching or walking bleaching.

The sodium perborate (Proderma, Piracicaba, Brazil) was manipulated the moment it was used in the ratio of 2 g of powder to 1 ml of distilled water.[23,24] The 37% CP (Whiteness® Super Endo - FGM Produtos Odontológicos, Joinvile, Brazil) came ready to be applied in the pulp chamber. The 35% HP (Whiteness® HP Maxx - FGM Produtos Odontológicos, Joinvile, Brazil) was manipulated in the ratio of three drops of HP to one drop of thickener.

Table 1. Bleaching materials and techniques used for each group.

Group	In-office Bleaching	Intracoronal Bleaching
G 1		SP
G 2	—	37% CP
G 3	—	35% HP
G 4	35% HP	CPW
G 5	35% HP	SP
G 6	35% HP	37% CP
G 7	35% HP	35% HP
G 8	—	CPW

The in-office bleaching agent was applied on the vestibular face of the teeth, at a thickness of 1 mm, and filled the pulp chamber. Three consecutive applications of the in-office bleaching agent were made. Light activation was done for 30 seconds immediately after the in-office bleaching gel was placed (G3 to G7) and after five minutes, as indicated by the manufacturer, using the "bleach" function of the Optilux 501 light curing unit (Demetron-Kerr, Danbury, CT, USA). The light intensity was measured with a radiometer at the beginning and end of its use in each group. Light intensity ranged from 900 to 1100 mW/cm^2.

The intracoronal bleaching materials were inserted to fill the pulp chamber, and a coronal seal was made with glass ionomer restorative cement (Maxxion R - FGM Produtos Odontológicos, Joinvile, Brazil). The bleaching agents were changed every seven days for three weeks. Groups G4 and G8 had the pulp chamber filled with a cotton pellet imbibed in distilled water followed by placement of a temporary restoration.

Specimen Preparation for Microtensile Bond Strength

After bleaching, the specimens were sectioned longitudinally in a low speed precision saw (Isomet 1000, Buehler Ltd., Lake Bluff, IL, USA), separating the lingual portion and exposing the inside of the pulp chamber, which was used for scanning electronic microscopy (SEM).

The facial portion of the teeth was sectioned again into two halves. One half of the facial surface of each specimen was used for microtensile test and the other half was ground on a water-cooled mechanical grinder using 600 and 1200-grit Al_2O_3 abrasive papers to obtain a flat dentin surface. Thereby, enamel and dentin bleached fragments were obtained for microtensile bond strength test.

Areas of 6 x 4 mm were delimited in dentin and enamel fragments. Seven days after the bleaching treatment the delimited area of each fragment was etched using 35% phosphoric acid gel (3M ESPE, St. Paul, MN, USA) for 15 seconds. After rinsing for ten seconds and blotting excess moisture, two consecutive coats of the adhesive Single Bond (3M ESPE, St. Paul, MN, USA) were applied, lightly air-dried, and light polymerized for ten seconds. A hybrid resin composite (Filtek Z250 - 3M ESPE, St. Paul, MN, USA) was inserted in two increments of 1.5 mm, which were polymerized for 20 seconds (Optilux 501).

Seven days after the restorative procedures, the enamel/resin and dentin/resin blocks were sectioned into small beams with a rectangular cross-sectional area of approximately 1 mm^2 using a speed precision saw.

The bonded surface area of each beam was calculated before testing by measuring the width and thickness using digital callipers (Mahr 16ES, Carl Mahr, Esslinger, Germany). The beams were fixed to matrices with cyanoacrylate adhesive and placed in a testing device. The microtensile test was performed in a universal testing machine (Instron 4411, Instron Corp., Canton, MA, USA) at a crosshead speed of 0.5 mm/min. The failure load and bonded area were used to calculate the bond strength of each beam.

Specimen Preparation for Scanning Electronic Microscopy (SEM)

For the SEM observation of the pulp chamber dentin surface, five bovine teeth per group (n=5) were randomly selected. After bleaching, the specimens were sectioned into two halves parallel to the longitudinal axis of the tooth using a low speed precision diamond saw (Isomet 1000, Buehler, Ltda) to expose inside the pulp chamber.

The exposed pulp chambers were rinsed in distilled water and debris was removed ultrasonically (1440 D) for one hour. The dentin pulp chamber sides were fixed in 2.5% glutaraldehyde (pH 7.2) and 0.2M cacodylate buffer for four hours at room temperature. The dentin surfaces were then dehydrated using an ascending ethanol concentration series (50, 60, 70, 80, 90, and 100%) for one hour each and dried in a Critical Point CPD 030 dryer (Balzer Pacific Equipment Co, Portland, OR, USA).

The specimens were mounted on aluminum stubs, gold-sputter coated (MED 010, BAL TEC, Furstentum FL-9496, Liechtenstein), and examined using a SEM (JEOL JSM 5600 LV, Jeol Datum, Tokyo, Japan). Microphotographs

were taken at standardized magnifications (500X, 1000X, and 2000X) to analyze the dentin surface.

Statistical Analysis

Mean bond strength for each tooth was calculated from the bond strength of the individual beams for enamel and dentin. Means were submitted to the analysis of variance (ANOVA) and Tukey tests (α=0.05) to compare the groups.

Results

Mean microtensile bond strength values and standard deviations for each group are summarized in Table 2. None of the bleaching techniques reduced the bond strength to enamel, but the groups G1 (intracoronal bleaching with SP) and G3 (intracoronal bleaching with 35% HP) showed significantly higher bond strength than other groups ($p<0.05$).

For dentin, all groups showed a lower bond strength than Group G8 (control) excepting Group G4 (in-office bleaching with 35% HP). However, the worst results were observed in the groups intracoronally bleached with sodium perborate (G1 and G5).

The SEM results demonstrated similar dentin surfaces for Groups G1, G2, G3, G6, and G7 (Figures 1A, 1B, 1C, 1F, and 1G), with more open dentin tubules than in the other groups. No odontoblastic filaments were observed in the dentin tubules in these groups. The presence of odontoblastic filaments was observed in Figures 1D and 1H, and the surface dentin was intact (groups G4 and G8 treated with water in the pulp chamber). Figure 1E (G5) demonstrated obliterated tubules and dentin surface roughness.

Discussion

Several studies have reported low concentrations of CP cause a reduction in bond strength to enamel and to dentin when a restorative procedure is performed immediately after bleaching.[25,26] The bond strength results after intracoronal bleaching with higher peroxide concentrations are still contradictory and can vary as a function of the bleaching agent used and

Table 2. Means (MPa) of enamel and dentin microtensile bond strengths for different bleaching techniques.

Group	Bleaching Agents		Enamel	Dentin
	In-office + Intracoronal		Mean (SD)	Mean (SD)
G1	-	SP	32.92 (3.55) [a]	10.15 (4.24) [c]
G2	-	CP	20.01 (7.74) [b]	20.95 (6.29) [b]
G3	-	HP	33.90 (3.43) [a]	16.97 (6.14) [b]
G4	HP	-	23.01 (4.14) [b]	22.56 (3.78) [ab]
G5	HP	SP	24.75 (5.38) [b]	10.86 (3.57) [c]
G6	HP	CP	23.45 (4.73) [b]	19.25 (2.71) [b]
G7	HP	HP	21.91 (3.07) [b]	20.00 (3.83) [b]
G8	-	-	19.22 (6.44) [b]	28.28 (6.34) [a]

Means followed by different letters are significantly different ($p<0.05$, Tukey's test).
SD = Standard Deviation

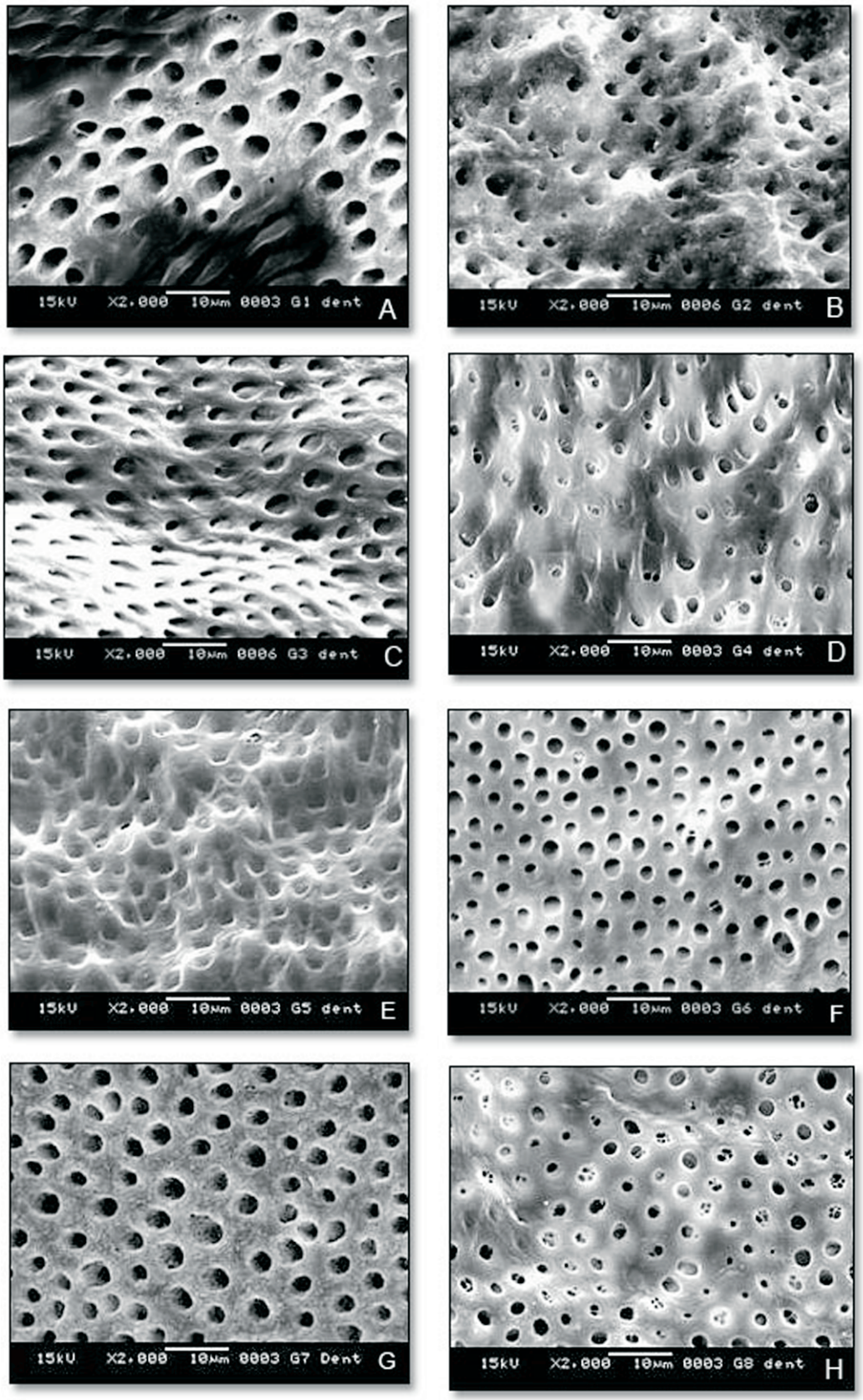

Figure 1. Surface dentin morphology in each group: **A.** Group G1. **B.** Group G2. **C.** Group G3. **D.** Group G4. **E.** Group G5. **F.** Group G6 **G.** Group G7. **H.** Group G8.

the time waited before performing the restorative procedure.[22,23,27]

There are still no data available about bond strength after combining in-office bleaching with intracoronal bleaching, which uses two forms of bleaching with high peroxide concentrations. In this study the intracoronal bleaching agents were placed inside the pulp chamber, simulating the clinical procedure as was done in the studies of Pécora et al.,[28] Chng et al.,[17] Teixeira et al.,[22] and Shinohara et al.[27] Thus, the bleaching agents reached the enamel and surface layer of dentin by diffusion via the dentinal tubules.[17]

In the present study no reduction in bond strength to enamel was observed in any of the groups, whether or not they were combined with in-office bleaching. Teixeira et al.[22] also observed no alteration in bond strength to enamel seven days after the end of intracoronal bleaching with 37% CP and with sodium perborate in combination with distilled water. These authors observed a reduction in bond strength to enamel only for the group bleached with a mixture of sodium perborate and 30% HP.

Whereas Shinohara et al.[23] observed when the restorative procedure is performed immediately after intracoronal bleaching with sodium perborate associated with distilled water or with 37% CP, a reduction in bond strength to enamel occurs irrespective of the adhesive system used.

Yet, in another study by Shinohara et al.[27] a reduction in bond strength to enamel was observed one day after and one week after the end of intracoronal bleaching with sodium perborate in combination with distilled water. Whereas bleaching with 37% CP diminished the bond strength to enamel only one day after the end of bleaching. The results of the present study confirm the data of Shinohara et al.[27] although one week after the end of bleaching would have been sufficient time to avoid a reduction of bond strength to enamel.

In another study Shinohara et al.[6] assessed marginal leakage in Class V restorations immediately after intracoronal bleaching with sodium perborate in combination with distilled water or with 37% CP. The bleaching treatments did not affect the marginal leakage of restorations at the margins in enamel but leakage increased at the dentin margins.

What has mostly been observed is a decrease of the bond strength to dentin after intracoronal bleaching. Teixeira et al.[24] observed no influence of time of postponing the adhesive procedure immediately after the end of intracoronal bleaching, after seven days, 14, or 21 days. These authors observed diminished bond strength in the groups bleached with sodium perborate associated with distilled water or with HP. Only bleaching with 37% CP did not affect the bond strength to dentin. Whereas Shinohara et al.[23] observed a reduction in bond strength to dentin only when the bleaching agent sodium perborate was used, while 37% CP did not affect bond strength irrespective of the adhesive system used.

With regard to in-office bleaching, its use in isolation or in combination with intracoronal bleaching did not cause an alteration in bond strength. Van der Vyver et al.[29] observed a reduction in bond strength to enamel after in-office bleaching with 35% HP when assessed immediately after the end of bleaching and after one week. Two weeks after bleaching no reduction in bond strength was observed. The results of the present study are compatible with this data because the bond strength was assessed seven days after the removal of the intracoronal bleaching agent and two weeks after the in-office bleaching.

Bronhara et al.[30] also observed no alterations in bond strength to enamel subjected to in-office bleaching with 35% HP or with 37% CP restored seven days after bleaching.

The results of the present study also drew attention to the higher bond strength observed in Groups G1 and G3 bleached intracoronally with sodium perborate and 35% HP, respectively.

With regard to sodium perborate, Lewinstein et al.[14] observed intracoronal bleaching with HP diminished the microhardness of enamel and dentin; when this material was used in combination with sodium perborate, this reduction did not occur. This was justified because sodium perborate rendered the pH of the mixture basic.

However, Rotstein et al.[31] observed intracoronal bleaching with HP reduced the level of calcium and the calcium/phosphorous levels of tooth enamel, while bleaching with sodium perborate did not affect these levels. As HP was used internally and/or externally in the other groups (with the exception of Group G2) in this study, perhaps the advantages of the use of sodium perborate appeared only in this group.

On the other hand, based on in-office bleaching studies, it can be noted the application of HP externally on enamel did not alter its bond strength.[29,30] Therefore, in Group G3 in which the in-office bleaching agent was applied inside the pulp chamber, the enamel bond strength would not be expected to be affected. However, the reason for the highest bond strength occurring in the control group is still unclear. One can only suppose the longer contact time with the dentin (inside the pulp chamber) caused the complete release of hydrogen ions and a large release of urea which could have caused some effect on the enamel through its diffusion.

Nevertheless, to explain this question of the higher bond strength observed in Groups G1 and G3, further studies need to be conducted to assess the composition of dental tissues before and after bleaching. Furthermore, other studies that assess enamel and dentin microhardness could complement the information obtained by the present study.

With regard to the surface pattern of intracoronal dentin, it was observed this pattern differs depending on the type of intracoronal bleaching agent used. However, the use of in-office bleaching gel does not appear to have interfered in the dentin pattern of the pulp chamber as observed using SEM.

Groups G1, G2, G3, G6, and G7 demonstrated a similar dentin surface pattern, with the presence of more open dentinal tubules than those in the other groups. In groups G6 and G7 the dentin was shown to be rougher, similar to the pattern of exposed collapsed collagen.

Using a cotton pellet with water intracoronally, Groups G4 and G8 (control) demonstrated the presence of odontoblastic prolongations at the opening of the dentinal tubules and smooth dentin, whereas Group G5 showed obliterated dentinal tubules. A probable hypothesis is the presence of remnants of bleaching gel in these teeth since the pulp chambers did not undergo any type of mechanical cleaning treatment, such as scraping with curettes and polishing with abrasive papers after removing the bleaching agents from inside them. The gel remnants could have stayed in the pulp chamber surface even with ultrasound cleaning. Furthermore, the concave configuration of the pulp chamber makes it difficult to remove the gel with the use of ultrasound only. Nevertheless, in order to observe the action of agents on the internal surfaces of pulp chambers it would be necessary for them to remain unaltered.

Conclusion

Based on the results of this study it could be concluded none of the bleaching techniques tested reduced the bond strength of enamel, but they all reduced the bond strength of dentin with the exception of the group bleached in-office only with 35% HP. However, the worst bond strength results to dentin were observed in the groups that had intracoronal bleaching done with SP (G1 and G5). Therefore, the combination of in-office bleaching with intracoronal bleaching does not worsen the bond strength of enamel or dentin and can be routinely performed in an endeavor to make bleaching more effective.

Clinical Significance

The combination of in-office with intracoronal bleaching of non-vital teeth can be performed to hasten the bleaching process without adversely affecting the bond strength of resin composite restorations to enamel and dentin.

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