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Effect of Tooth Bleaching on Bond Strength of Enamel-Dentin Cavities Restored With Silorane- and Dimethacrylate-based Materials

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Clinical Relevance

Prior bleaching treatment, with both low and high concentrations of bleaching agents, does not affect the push-out bond strength of dimethacrylate- and silorane-based materials to enamel-dentin cavities.

SUMMARY

The aim of this study was to evaluate the influence of tooth bleaching on the push-out bond strength of a composite resin based on dimethacrylates and silorane to cavities that involve both enamel and dentin. A total of 80 bovine incisors were sectioned on the buccal surface to obtain specimens (10 × 10 mm) presenting enamel and dentin (1-mm thick

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each substrate). The specimens were randomly distributed into eight groups (n=10), according to the bleaching protocol (1—none; 2—10% carbamide peroxide [CP] for 21 days, six hours each day; 3—three applications of 35% hydrogen peroxide [HP] in 15-minute sessions, one session every seven days for three weeks; 4—10% CP for 18 days, six hours each day + three applications of 35% HP in 15-minute sessions, one session every seven days for three weeks) and the restorative system applied (Adper Single Bond 2 + Filtek Supreme; Filtek Silorane adhesive and composite resin). After treatment, cavities were made (1.2-mm diameter on dentin; 1.5-mm diameter on enamel) with a diamond bur. At 24 hours after restoration, a push-out bond strength test was performed at a crosshead speed of 0.5 mm/min. The bleaching treatments did not significantly affect the bond strengths of either restorative system to enamel-dentin. Regardless of the bleaching treatment, the dimethacrylate-based resin system exhibited significantly higher bond strengths to enamel-dentin than did the silorane-based system.

INTRODUCTION

Dental bleaching has been widely studied, with most of the research related to side effects, such as toxic effects on the pulp cells,[1-4] deleterious effects on dental pulp,[5,6] decreases in microhardness of the bleached substrate,[7-10] and the deleterious effect of bleaching on the bond strength of resin materials.[11-14]

One of the theories regarding the deleterious effect of bleaching on the bond strength of resin materials is related to the decrease in bond strength with the reactive oxygen species (ROS) release by the bleaching agents and the accumulation of these ROSs on the bleached tooth structure. After an adhesive system is applied, the oxygen reacts with the ends of the forming polymeric chains, ending the polymeric elongation and reducing the degree of conversion of the adhesive systems and composite resins,[15] causing a decrease in the bond strength.

Nevertheless, the effect of the residual oxygen on the bonding of the resin agents is linked to the direct application of the bleaching agent on the surface to be restored. Lima and others,[14] using agents with both low and high concentrations, demonstrated that enamel bleaching does not have an influence on the bond strength to subjacent dentin. Thus, the decrease in bond strength to dentin, after bleaching, is restricted to cases where the bleaching agents are applied directly on the substrate that will be restored.

A new resin system with low shrinkage is currently offered, with different monomers than the conventional composite resin based on bisphenol A diglycidyl ether dimethacrylate (Bis-GMA). The polymeric formation from the opening of the silorane rings reduces the shrinkage of this material,[16] decreasing the possibility of gap formation and microleakage at the tooth/restoration interface. However, the influence of bleaching on the bond strength of the silorane-based materials to the bleached substrate is still unknown.

After a bleaching treatment, it is necessary to evaluate the bond strength of both silorane- and dimethacrylate-based materials to cavities containing enamel and dentin to achieve restorations with a good prognosis.

Therefore, the aim of this current study was to evaluate whether different bleaching treatments can interfere with the push-out bond strength to enamel-dentin cavities restored with silorane- or dimethacrylate-based materials. The null hypothesis of the present study was that none of the bleaching treatments would significantly affect the push-out bond strength of the resin materials to enamel-dentin cavities. The second hypothesis was that the evaluated restorative systems would present similar bond strengths.

MATERIALS AND METHODS

The information of the materials used in the present study is listed on Table 1.

A total of 80 bovine incisors were collected, cleaned, and stored in 0.1% thymol solution. The selected teeth were examined under a stereomicroscope (20× magnification, Meiji 200, Meiji Techno, Tokyo, Japan) to guarantee that they were free of cracks or other defects in the enamel that could possibly affect the results.

Each tooth was sectioned perpendicular to the buccal surface using double-faced diamond disks (no. 7020, KG Sorensen, Barueri, SP, Brazil) in a low-speed hand-piece, obtaining one fragment of 10 mm on each side per tooth (Figure 1A). The thickness of the specimen was standardized at 2 mm (1 mm enamel and 1 mm dentin) (Figure 1B). The width/length and the thickness of enamel and dentin of each fragment were standardized using a digital caliper (Mitutoyo Sul Americana, São Paulo, SP, Brazil).

Table 1: *Names, Composition and Manufacturers of the Products Used in the Present Study*

Product	Composition	Manufacturer
Carbamide peroxide (CP) 10% - Whiteness Perfect	Carbamide peroxide, sodium fluoride, potassium nitrate	FGM Produtos Odontológicos, Joinvile, SC, Brazil
Hydrogen peroxide (HP) 35% - Whiteness HP	Hydrogen peroxide	FGM Produtos Odontológicos, Joinvile, SC, Brazil
Dimethacrylate system - Filtek™ Supreme	Silane-treated ceramic, bisphenol A polyethylene glycol diether dimethacrylate, diurethane dimethacrylate, silane-treated silica, bisphenol A diglycidyl ether methacrylate, triethylene glycol dimethacrylate, water	3M ESPE, St Paul, MN, USA
Scotchbond Etching Liquid	Water, phosphoric acid 35%	3M ESPE, St Paul, MN, USA
Adper Single Bond 2	Ethyl alcohol, silane-treated silica (nano-filler), bisphenol A diglycidyl ether dimethacrylate (BisGMA), 2-hydroxyethyl methacrylate, glycerol 1,3-dimethacrylate, copolymer of acrylic and itaconic acids, water, diurethane dimethacrylate	3M ESPE, St Paul, MN, USA
Silorane system - Filtek™ Silorane	Silane-treated quartz, 3,4-epoxycyclohexylcyclopolymethylsiloxane, yttrium trifluoride, bis-3,4-epoxycyclohexylethyl-phenyl-methylsilane, mixture of epoxyfunctional di- and oligo-siloxane by-products, mixture of alpha-substituted by-products, mixture of other by-products, mixture of epoxy-mono-silanole by-products	3M ESPE, St Paul, MN, USA
Self-etching primer	2-hydroxyethyl methacrylate (HEMA), bisphenol A diglycidyl ether dimethacrylate (BisGMA), water, ethanol, phosphoric acid-methacryloxy-hexylesters, silane-treated silica, 1,6-hexanediol dimethacrylate, copolymer of acrylic and itaconic acid, (dimethylamino)ethyl methacrylate, DL-camphorquinone, phosphine oxide	3M ESPE, St Paul, MN, USA
Silorane Bond agent	Substituted dimethacrylate, silane-treated silica, triethylene glycol dimethacrylate (tegdma), phosphoric acid methacryloxy-hexylesters, 1,6-hexanediol dimethacrylate, DL-camphorquinone	3M ESPE, St Paul, MN, USA

To obtain the specified thickness of both enamel and dentin, surfaces were ground flat with 600-grit aluminum oxide papers (Arotec Ind Com Ltd, Cotia, SP, Brazil) under constant water cooling. The fragments were randomly divided into eight groups (n=10) in accordance with the bleaching protocol (1—none; 2—10% carbamide peroxide [CP] for 21 days, six hours each day; 3—three applications of 35% hydrogen peroxide [HP] in 15-minute sessions, one every seven days for three weeks; 4—10% CP for 18 days, 6 hours each day + three applications of 35% HP in 15-minute sessions, one session every seven days for three weeks) and the restorative system applied (Adper Single Bond 2 + Filtek™ Supreme; Filtek™ Silorane - 3M ESPE, St. Paul, MN, USA) adhesive and composite resin).

The bleaching procedures were performed on enamel, with the gel applied in such a way that the surface was totally covered by the product (Figure 1C). At the end of the bleaching protocol performed each day, the specimens were washed and stored in

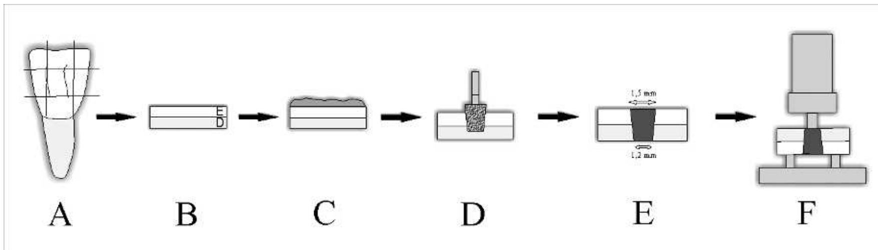

Figure 1. *Schematic study design. (A): Bovine incisor with the central area marked, delineating the sections (10 × 10 mm) on the buccal surface. (B): Tooth fragment after standardization of the thickness (1 mm enamel and 1 mm dentin). (C): Specimen with bleaching gel applied, covering the enamel surface. (D): Cavity preparation using a diamond bur no. 2130. (E): Specimen with the cavity restored. (F): Lateral view of the push-out test system.*

artificial saliva[17] (artificial saliva prepared by Proderma, Piracicaba, SP, Brazil).

At the completion of bleaching for each group, the teeth were maintained in artificial saliva for 24 hours, and then the restorative procedure was performed. To create the cavities, the specimens were fixed on the device to standardize the preparation, and the cavities were created (2-mm depth; 1.2-mm diameter in dentin and 1.5-mm diameter in enamel) with a high-speed hand-piece (Kavo EXTRATorque 605, Fábrica KaVo do Brasil Ind Com Ltda, Joinville, SC, Brazil), under constant water cooling, with use of a conical shaped diamond bur (no. 2031, KG Sorensen, Barueri, SP, Brazil) (Figures 1D,E).

For the groups restored with the dimethacrylate material, both the dentin and enamel surfaces were prepared by etching with 35% phosphoric acid (Scotchbond Etching Liquid - 3M ESPE, St. Paul, MN, USA) for 15 seconds, washed for 15 seconds, and dried with absorbent papers, maintaining a lightly moist dentin surface. A one-bottle adhesive system was then applied (Adper Single Bond 2) according to the manufacturer's instructions: in two consecutive layers intercalated by a 5-second air-spray. The adhesive system was light-cured for 10 seconds. The restoration was filled with a composite resin (Filtek™ Supreme A2) in two horizontal increments (1 mm thick), with each light-cured for 20 seconds according to the manufacturer's instructions.

The groups restored with the silorane-based composite resin (Filtek™ Silorane) used the dental adhesive required by the restorative system, according to the manufacturer's instructions: application of the primer agent, gentle air-spray and light-curing for 10 seconds, followed by bond application and light-cure for 10 seconds. The composite resin was placed in the cavities in two horizontal increments (1 mm thick) and light-cured for 40 seconds, in accordance with the manufacturer's instructions. The restorations, with both silorane and dimethacrylate materials, were performed with the specimens under a glass slide on the dentin and enamel surfaces, to provide flat surfaces for the restorations.

Both the adhesive system and the composite resin were photo-activated with a quartz-tungsten halogen lamp (Demetron LC, Sybron Kerr, Danbury, CT, USA), which had its irradiance constantly monitored at around 650 mW/cm^2.

Bond Strength Test (Push-out)

At 24 hours after restoration, the samples were placed on a metallic base with a central hole (3-mm diameter) and fixed to a load-testing machine (EMIC DL 500, São José dos Pinhais, SC, Brazil), to perform the push-out bond strength test. The specimens were positioned in such way that the restoration was centralized with the hole, with the enamel face down, according to previous studies.[18,19] The samples were then stressed to failure at a crosshead speed of 0.5 mm/min (Figure 1F). The data obtained in kilogram force were converted to megapascals, with the maximum load divided by the bonded surface area of each sample.

Statistical Analysis

Sample size was calculated with data from a pilot study, considering a power of 80%. The normality of the data was analyzed (Kolmogorov-Smirnov and Shapiro-Wilk tests), and a two-way analysis of variance and Tukey test (α=0.05) was applied. The main variables were bleaching protocol and restorative system.

RESULTS

The results are shown in Table 2. The variable, bleaching protocol, and the interaction between the variables, bleaching protocol × restorative system,

Table 2: *Means (Standard Deviations) of the Control and Experimental Groups of the Present Study*

	Filtek Supreme	Filtek Silorane
Control	24.72 (6.51) A[a]	18.85 (5.93) B
CP 10%	19.62 (3.64) A	18.6 (6.84) B
HP 35%	18.5 (5.48) A	17.23 (3.84) B
CP 10% + HP 35%	22.16 (5.07) A	18.66 (4.08) B

[a] *Different letters represent significant statistical difference within the composite resin groups (two-way analysis of variance and Tukey α=0.05).*

were not statistically significant. Only the restorative systems presented a significant difference, with the dimethacrylate-based system presenting higher push-out bond strength values than the silorane composite resin, independent of the bleaching protocol.

DISCUSSION

The present study evaluated the influence of different bleaching protocols on the push-out bond strength of resin materials to enamel-dentin cavities. Despite the different concentrations of bleaching agents and different application protocols, the bond strengths of the restorative systems based on silorane and dimethacrylate were not adversely affected. Therefore, the main hypothesis of the present study was accepted.

The bleaching agents act with the formation and release of an ROS, like hydrogen peroxide and hydroxyl radicals (OH^-), interacting chemically with the long chains of the pigments, breaking these into smaller molecules and making the teeth clearer.[20] However, at the end of the treatment, large amounts of residual oxygen present on the bleached substrate can compromise the bonding of resin materials to this surface.[12,13] Due to the high reactivity of the ROS, premature termination of the polymeric chains occurs, compromising the quality of the polymers formed[15] and decreasing the bond strength of the resin materials to the dental structure.

The present study demonstrates that after the bleaching treatment, the push-out bond strength of resin materials to cavities containing enamel and dentin is not affected. The bonding to superficial enamel is compromised after bleaching, as has been described by several studies.[11-13,21] However, the subjacent dentin is not affected.[14] Despite the occurrence of the diffusion of the bleaching subproducts through the dentin,[22,23] the radicals present on the dentin are probably incapable of affecting the curing of the resin adhesives, reducing the bond strength.[14]

When the restoration involves both enamel and dentin, the reduction of the bond strength to the superficial enamel appears to be minimal, as seen by the results of the present study. This can be due to the other areas involved, which promote effective bonding between restorative materials and tooth structure. The push-out bond strength test is sensitive to the material combination, specimen geometry, and fixture conditions,[24] in addition to the substrate structure. Nevertheless, because the same methodology was used for all the specimens, except for the different treatment, the areas not affected by the bleaching agents should be considered to explain the obtained results after treatment.

Microleakage is a factor to be considered in situations when enamel-dentin cavities are restored after bleaching treatments. Crim[25] demonstrated in a 1992 report that prior bleaching does not influence the microleakage of resin composite restorations to bleached teeth. Yazici and others (2010),[26] in a recent study, found that microleakage increased in restorations placed after bleaching and submitted to thermocycling; however, this increase is dependent on the adhesive system. Despite the conflicting results, the data obtained in the present study validate the effectiveness of the bond between the surrounding walls of the preparation and resin adhesive systems after bleaching.

The push-out bond strength was not affected by the bleaching treatment; nevertheless, the dimethacrylate-based restorative system showed higher values of bond strength than the silorane system did. Therefore, the second hypothesis of the present study was rejected. These results can be due to the different presentation of the adhesive systems.

Self-etching adhesives exhibit lower bond strengths to enamel than do the etch-and-rinse systems, as described by some studies.[27,28] Therefore, the weaker bonding to enamel might have caused the lower push-out bond strength values compared with the dimethacrylate system because the cavities consisted of enamel and dentin, with enamel having the largest surface area.

In addition, the silorane restorative system presents a different two-bottle adhesive system. The primer agent of this system is light-cured and, after the light activation, the bond agent is applied over the primer layer. Therefore, the primer agent of this system is responsible for creating the hybrid layer, in contrast with the conventional self-etching adhesive systems, which form the hybrid layer with a mix of primer and bond agent.

Thus, the adhesive of the silorane system produces a tooth-resin composite interface that is composed of the tooth structure; a hybrid layer formed by the primer agent; a bond applied over the primer, working as an intermediate resin with low viscosity; and the composite resin. Due to this complicated process, a weak bonding between the two substrates cited can compromise the bond strength of this new restorative system.

The current results reinforce the idea of the individuality of clinical cases. In cases that involve only superficial enamel, the negative influence of previous bleaching treatment should be considered. However, in cases that involve cavities with enamel and dentin substrates, the effect of bleaching on bond strength appears to be minimal.

CONCLUSIONS

As a result of the experimental conditions and obtained data, it can be concluded as follows:

1. Bleaching treatment does not influence the push-out bond strength of resin materials based on either dimethacrylate or silorane to enamel-dentin cavities, independent of the bleaching protocol used.
2. The restorative system based on dimethacrylate presented significantly higher push-out bond strengths to cavities that contain enamel and dentin, compared with the silorane-based material.

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