In Situ Effect of 10% Carbamide Peroxide on Resin-Dentin Bond Strengths: A Novel Pilot Study

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ABSTRACT

Purpose: This pilot study used a novel study design to evaluate the effect of a 10% carbamide peroxide bleaching gel on the bond strength of a resin-based composite system to dentin.

Materials and Methods: Dentin disks were obtained from human third molars, polished to 600 grit, and mounted on the palatal aspect of a removable orthodontic retainer. Two disks were exposed to a 10% carbamide peroxide bleaching gel for 2 h/d for 21 days, whereas two disks were not treated and served as controls. A retainer was worn by the participant regardless of whether bleaching was used, simulating the action of the saliva/oral fluids on the dentin specimens. After the treatment phase, the dentin disks were retrieved and a resin-based composite system was applied to the specimens following manufacturer's instructions. Composite dentin "sticks" were obtained and tested in microtensile mode. Bond strength values were obtained for treated ($n = 20$) versus nontreated ($n = 26$) dentin and were analyzed statistically.

Results: Mean bond strengths values (SD) were 29.9 MPa (6.2) and 39.2 MPa (5.8) for treated and nontreated dentin specimens, respectively ($p < .001$).

Conclusion: The results of this study suggest that nightguard (home) bleaching with 10% carbamide peroxide for 2 h/d for 21 days significantly affects resin-dentin bond strengths when dentin is exposed to bleaching material.

CLINICAL SIGNIFICANCE

The findings of this novel pilot study imply that dentin bonding, such as to exposed root surfaces and cervical areas of the teeth, should not be performed immediately after bleaching with 10% carbamide peroxide.

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For a long time, the esthetic treatment of discolored teeth required invasive procedures such as jackets and crowns. Bleaching techniques offer a conservative treatment alternative for discolored teeth. In particular, home bleaching, introduced in 1989 by Haywood and Heymann,[1] has been consistently described as a safe and effective treatment alternative for vital discolored teeth.[2–4] The bond strength of resin composites to recently bleached enamel has been investigated. It has been reported that resin to enamel bond strengths decrease immediately after home bleaching, and that bond

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strengths return to pretreatment levels after 2 weeks.[5–8] The initial reduction in enamel bond strengths has been attributed mostly to residual oxygen in the enamel,[9,10] although one study suggested enamel surface alterations could be responsible for the reduction in bond strengths.[11] Although the precise cause for the reduction in bond strength is debatable, it has been accepted that enamel bond strength values return to normal levels owing to the diffusion of any remaining oxygen and/or to the reparative action of saliva. The initial reduction in enamel bond strengths after bleaching is clinically significant because many patients require replacement of existing esthetic restorations after bleaching treatment. Based on this potential drawback, it has been recommended that adhesive restorative procedures be delayed for at least 2 weeks after bleaching.[6]

Physiologic gingival recession and root caries are common in many adults and in the elderly. With increased life expectancy observed in many countries, more adhesive restorative procedures involving root surfaces with cervical dentin margins will be performed. As bleaching treatments are sought by individuals of all ages, it seems appropriate to investigate the effect of bleaching treatment not only on enamel but also on dentin. Laboratory studies have reported a reduction in resin-to-dentin bond strength values after bleaching treatment.[12,13] However, a significant limitation of in vitro bleaching studies is the lack of a realistic treatment regimen. It is difficult to simulate in vitro the effect of intraoral factors such as saliva on treated enamel and dentin.

The purpose of this novel pilot study was to analyze in situ the effects of a home-bleaching treatment on the resin-to-dentin bond strengths.

MATERIALS AND METHODS

The protocol for this study was reviewed and approved by the Federal University of Santa Catarina's Committee of Ethics in Research.

Bleaching Treatment

This pilot study involved the participation of a 21-year-old male. Before the initiation of the study, the participant read and signed an informed consent form. Inclusion criteria included the absence of dental caries and/or periodontal disease, the absence of extensive restorations and/or prostheses in the anterior dentition, overall good health, anterior teeth shade A3 or darker according to the Vita Lumin Vacuum® shade guide (Vita Zahnfabrik, Bad Säckingen, Germany) arranged in order of value according to the manufacturer's instructions, and four third molars with extraction indicated.

A full-arch maxillary impression was obtained and poured in stone. The third molars were then extracted, identified, and kept in a 0.2% thymol solution.

The occlusal surfaces of the specimens were ground flat to expose the dentin and polished to 600 grit (Norton A'cqua Flex, São Paulo, Brazil) using an automatic grinding machine (DP 10®, Struers-Panambra, Rødovre, Denmark). Three millimeter–thick dentin disks were then obtained by sectioning the specimens with a water-cooled ultrathin flexible diamond disk (Buehler Ltd., Lake Bluff, IL, USA) in a slow-speed circular sectioning machine (Isomet 4000®, Buehler Ltd.). Four dentin disks were obtained—one from each extracted third molar (Figure 1).

An intraoral removable acrylic appliance was fabricated using the stone model. Two sets of dentin disks were mounted on the palatal side of the appliance. One set was fixed, and the other set was removable to avoid the contact of control specimens with the bleaching gel (Figure 2). The appliance was kept in a moist environment until the initiation of the clinical phase of the study.

A 0.089 cm (0.035 in.) modified bleaching tray was fabricated. During tray fabrication, the removable appliance was seated on the corresponding stone model. Consequently, the bleaching tray fit the participant's maxillary arch and covered the removable appliance (Figure 3).

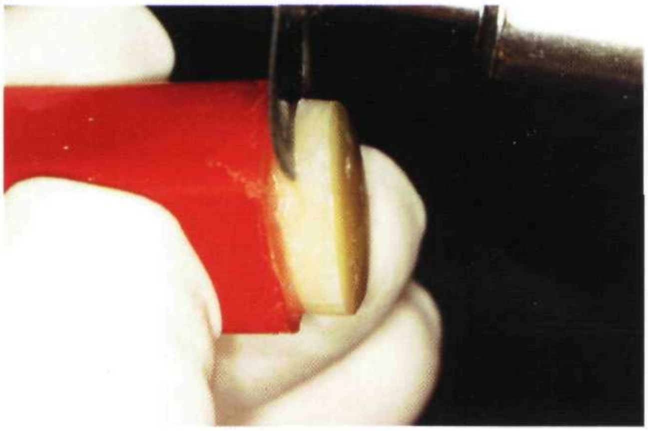

Figure 1. Flat dentin disks were obtained from human third molars.

The participant was given thorough written and verbal instructions concerning the study and treatment regimen. He was instructed to use the removable appliance containing the dentin specimens obtained from his third molars for 24 h/d for 21 days. This approach ensured exposure of the dentin specimens to intraoral conditions. The removable appliance was to be removed only during meals and for oral hygiene purposes. During the extraoral time, the appliance was kept in a moist container with fresh tap water. The participant was instructed not to use a toothbrush or any other cleaning device on the dentin specimens. Only the internal aspect of the appliance could be cleaned with a toothbrush and toothpaste, if so desired.

During bleaching treatment the participant was instructed to take out the removable set of dentin disks (control) from the appliance and keep it in fresh artificial saliva. The treatment gel used was a thick 10% carbamide peroxide gel, Nite White Excel® 2Z (lot no. 0FAA-0FAC, Discus Dental Inc., Culver City, CA, USA), with a pH of 6.9. The participant was instructed to load the tray with the gel and use it for 2 h/d (Figure 4). After each use, both the bleaching tray and the appliance were removed and rinsed under running tap water, and the removable set of dentin disks was repositioned; the appliance was kept in the participant's mouth for the remaining time.

With this regimen, only one set of dentin disks was treated; the other set served as a nontreated control. A treatment regimen of 21 days was elected based on the protocol for home-bleaching treatment adopted at the Federal University of Santa Catarina.

Figure 2. Two sets of dentin disks were mounted on the palatal side of a removable appliance. One set (experimental) of dentin disks was fixed, and the other set (control) was removable to avoid the contact of control specimens with the bleaching gel.

Measurement of Microtensile Bond Strengths

After conclusion of the bleaching treatment, the appliance was collected and the dentin sets were retrieved. Dentin specimens were rinsed thoroughly under running water, and a resin-based composite (Filtek Z-250™, lot no. OBG/OBP, 3M ESPE, St. Paul, MN, USA) was applied to the dentin surfaces following the manufacturer's instructions. Specifically, dentin was etched with a 35% phosphoric

Figure 3. A modified bleaching tray was fabricated. Note the foam pad built in the tray to act as a reservoir for the bleaching material.

acid gel (3M ESPE) for 15 seconds, rinsed thoroughly with water, and blot dried. Two coats of and ethanol- and water-based adhesive (Single Bond, lot. no. 1FT, 3M ESPE) were applied to the wet dentin surface, slightly dried, and light cured (Optilux 500®, Demetron Research Corp., Danbury, CT, USA). Filtek Z-250 was applied in 1 mm–thick increments light cured individually for 20 seconds. Three increments of resin composite were used.

Specimens were then mounted to an acrylic support using cyanoacrylate and sectioned with a diamond wafering blade (Buehler Ltd.) operating in a slow-speed wet saw (Isomet 4000). Composite dentin sticks measuring 1 × 1 × 6 mm were obtained from each dentin disk. Peripheral enamel composite specimens were discarded. A total of 20 sticks were obtained from the treated dentin, and 26 sticks were obtained from nontreated dentin.

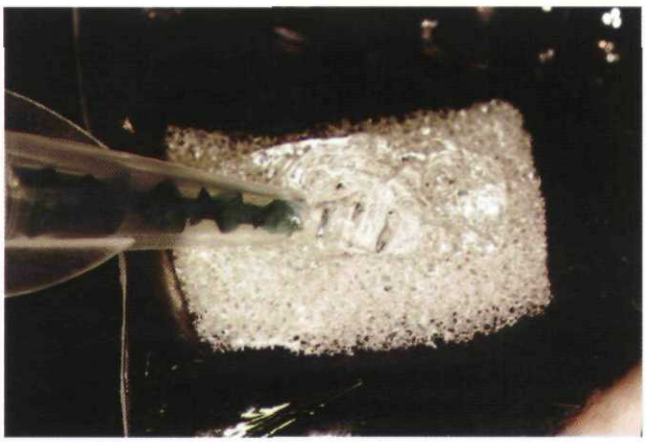

Figure 4. Bleaching gel being applied on the foam pad immediately before seating the bleaching tray on the appliance.

Each stick was tested individually for microtensile bond strengths. The stick was attached to a Bencor Multi-T® device (Danville Engineering, San Ramon, CA, USA) mounted in a Instron® Universal Testing machine (model 4444, Instron Co., Canton, MA, USA). The crosshead speed was set at 0.5 mm/min.[14–16] Specimens were attached parallel to the microtensile force and tested to fracture. The force required to debond the specimens was expressed in newtons. These values were then divided by the bonded area (1 mm^2), and the final microtensile bond strength was expressed in megapascals.

Microtensile bond strength values were analyzed for statistical significance with student's t-test ($p = .05$) using ARCUS 2.0 Professional® software (Research Solutions, Cambridge, UK).

RESULTS

Results are presented in Table 1. Mean microtensile bond strength values ranged from 29.9 (± 6.2) MPa (treated dentin; $n = 20$) to 39.2 (± 5.8) MPa (nontreated dentin; $n = 26$). Statistical analysis revealed that resin-dentin bond strengths were significantly affected by the bleaching treatment. The mean bond strength to treated dentin was

TABLE 1. MEAN MICROTENSILE BOND STRENGTH VALUES.

	Control (Nontreated)	Treated 2h/d*
n	26	20
Mean MPa (SD)	39.2 (5.8)	29.9 (6.2)
p Value	< .001	

*Treated in situ with 10% carbamide peroxide gel for 21 days.

significantly lower than was the mean bond strength to nontreated dentin ($p < .001$).

DISCUSSION

Since bleaching products are usually applied only on enamel, little is known about their effects on dentin. Enamel and dentin are permeable to carbamide peroxide components, and enamel bleaching potentially affects dentin. In addition, contact of bleaching materials with cervical aspects of teeth not covered by enamel is not uncommon, especially in aging individuals with areas of localized or generalized gingival recession.

One of the most clinically significant effects of bleaching treatments on enamel is the reduction in resin-to-enamel bond strengths noticed immediately or for several days after completion of bleaching treatment.[2,6,17–19] It has been suggested that the reduction in bond strength could be caused by an accumulation of oxygen in dentin since dentin acts as an oxygen reservoir.[6,20] However, some authors maintain that this reduction is not related to the inhibition of resin polymerization brought about by the accumulation of residual oxygen on treated enamel.[13,21] Sung and colleagues have stated that this decrease in enamel adhesion can be affected by the type of adhesive used.[7] These authors reported that an alcohol-based bonding agent (OptiBond®, Kerr Manufacturing Co., Romulus, MI, USA) is capable of reducing or eliminating the negative effects of residual oxygen on the process of adhesion of composites to enamel.

Reduction in resin-to-dentin bond strengths after bleaching treatment also has been reported.[11,12,22] Peroxide-based substances, when applied directly on dentin, react with the smear layer on the dentinal surface. This interaction forms attached granular deposits not removed by the acids used in the adhesive procedures.[11,22] Toko and Hisamitsu reported that the reduction of adhesion can be related to the alteration of the dentin organic content.[12]

However, these in vitro studies do not consider many of the clinical variables present when bleaching teeth in vivo. Factors such as dentin thickness, sclerosis of dentinal tubules, and, most importantly, natural saliva are clinical variables that can significantly influence the effect of bleaching treatment on dentin.[23]

Our in situ study attempted to simulate as much as possible the in vivo conditions of bleaching treatment. Dentin specimens for this study were kept in the oral cavity in contact with saliva whenever they were not exposed to the bleaching treatment.

One limitation pertinent to this study design has to be acknowledged. The bleaching agent used (Nite White Excel 2Z) contains potassium nitrate, which is included to reduce the potential for sensitivity during and immediately after bleaching. It is conceivable that the effect of bleaching on bond strengths observed in our study is due in part to the potassium nitrate and not to the bleaching active ingredient. Further studies with different bleaching materials without desensitizing agents need to be conducted to rule out this hypothesis.

A recent study showed that the dentinal tubule orientation plays an important role in bond strengths.[24] According to this study, bonding to oblique dentinal tubules generates significantly higher mean bond strength values than does bonding to parallel or perpendicular dentinal tubules. In our study we bonded primarily perpendicularly and obliquely to dentinal tubules, which would be the case when bonding to cervical areas of teeth where dentin becomes exposed owing to gingival recession.

Microtensile bond strength tests are labor intensive but have the potential to generate relevant adhesion information, particularly with multiple bond strength measurements from a single tooth.[25,26] This in situ study with a single participant allowed us to eliminate a number of variables, such as compliance issues, saliva characteristics, and hygiene habits. Studies involving more participants have the potential disadvantage of difficult standardization and poor compliance. In addition, the number of specimens tested in this study ($N = 46$) was sufficient to generate statistically relevant results and is comparable to sample sizes used in other studies of microtensile bond strength.[25,26]

More studies are needed to broaden the knowledge base on the effects of 10% carbamide peroxide on dentin. Based on the results of this preliminary study, one of these effects might be the formation of subproducts that compromise the interaction of an ethanol- and water-based adhesive with etched dentin. Since dentin is more permeable than enamel, peroxides can potentially diffuse more through dentin than through enamel. Further studies should investigate the time required for the resin-to-dentin bond strength to return to pretreatment levels, as well as the effect on dentin bond strengths of different bleaching materials, treatment regimens, and adhesives.

CONCLUSION

Based on the results of this pilot study, at-home bleaching using a 10% carbamide peroxide gel for 2 h/d for 21 days might significantly affect resin-dentin bond strengths when adhesive procedures are performed on dentin exposed to the bleaching treatment. To confirm these results and verify their clinical relevance, a larger study involving more participants is necessary.

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REFERENCES

1. Haywood VB, Heymann HO. Nightguard vital bleaching. Quintessence Int 1989; 20:173–176.
2. Li Y. Biological properties of peroxide-containing tooth whiteners. Food Chem Toxicol 1996; 34:887–904.
3. Pesun JI, Madden RM. A review of the current status of vital bleaching. Northwest Dent 1999; 78:25–33.
4. Haywood VB. Current status of nightguard vital bleaching. Compend Contin Educ Dent 2000; 21:10–17.
5. Cullen DR, Nelson JA, Sandrik JL. Peroxide bleaches: effect on tensile strength of composite resins. J Prosthet Dent 1993; 69:247–249.
6. Swift EJ Jr, Perdigão J. Effects of bleaching on teeth and restoration. Compend Contin Educ Dent 1998; 19:815–820.
7. Sung EC, Chan SM, Mito R, Caputo AA. Effects of carbamide peroxide bleaching on the shear bond strength of composite to dental bonding agent enhanced enamel. J Prosthet Dent 1999; 82:595–599.
8. Novais RCP, Toledo OA. Estudo in vitro das alterações do esmalte dentário submetido à ação de um agente clareador. Jornal Brasileiro de Clínica e Estética em Odontologia 2000; 4:48–51.
9. Hunsaker KJ, Christensen JG, Christensen RP. Tooth bleaching chemicals' influence on teeth and restorations. J Dent Res 1990; 69:303.
10. Shannon H, Spencer P, Gross K, Tira D. Characterization of enamel exposed to 10% carbamide peroxide bleaching agents. Quintessence Int 1993; 24:39–44.
11. Perdigao J, Francci C, Swift EJ Jr, Ambrose WW, Lopes M. Ultra-morphological study of the interaction of dental adhesives with carbamide peroxide–bleached enamel. Am J Dent 1998; 11:291–301.
12. Toko T, Hisamitsu H. Shear bond strength of composite resin to unbleached and bleached human dentin. Asia J Aesthet Dent 1993; 1:33–36.
13. Spyrides GM, Perdigao J, Pagani C, Araujo MA, Spyrides SM. Effect of whitening agents on dentin bonding. J Esthet Dent 2000; 12:264–270.
14. Cardoso PEC, Braga RR, Carrilho MRO. Evaluation of micro-tensile, shear and tensile tests determining the bond strength of three adhesive systems. Dent Mater 1998; 14:394–398.
15. Carvalho RM, Santiago SL, Fernandes CA, Suh BI, Pashley DH. Effects of prism orientation on tensile strength of enamel. J Adhes Dent 2000; 2:251–257.
16. Cardoso PEC, Carrilho MR, Francci CE, Perdigao J. Microtensile bond strengths of one-bottle dentin adhesive. Am J Dent 2001; 14:22–24.
17. Leonard RH Jr, Haywood VB, Phillips C. Risk factors for developing tooth sensitivity and gingival irritation associated with nightguard vital bleaching. Quintessence Int 1997; 28:527–534.
18. McCracken MS, Haywood VB. Demineralization effects of 10 percent carbamide peroxide. J Dent 1996; 24:395–398.
19. Bowles WH, Ugwuneri Z. Pulp chamber penetration by hydrogen peroxide following vital bleaching procedures. J Endod 1987; 13:375–377.

20. Spyrides GM, Perdigão J, Pagani C, Araujo MA, Spyrides SM. Effect of whitening agents on dentin bonding. J Esthet Dent 2000; 12:264–270.

21. Van Meerbeek B, Perdigão J, Lambrechts P, Vanherle G. The clinical performance of adhesives. J Dent 1998; 26:1–20.

22. Titley KC, Torneck CD, Smith DC. Effect of concentrated hydrogen peroxide solution on the surface morphology of cut human dentin. Endod Dent Traumatol 1988; 4:32–36.

23. Hanks CT, Fat JC, Wataha JC, Corcoran JF. Cytotoxicity and dentin permeability of carbamide peroxide and hydrogen peroxide vital bleaching materials "in vitro". J Dent Res 1993; 72:931–938.

24. Liu J, Hattori M, Hasegawa K, Yoshinari M, Kawada E, Oda Y. Effect of tubule orientation and dentin location on the microtensile strength of bovine root dentin. Dent Mater J 2002; 21:73–82.

25. Sano H, Shono T, Sonoda H, et al. Relationship between surface area for adhesion and tensile bond strength—evaluation of a micro-tensile bond test. Dent Mater 1994; 10:236–240.

26. Pashley DH, Carvalho RM, Sano H, et al. The microtensile bond test: a review. J Adhes Dent 1999; 1:299–309.

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COMMENTARY

IN SITU EFFECT OF 10% CARBAMIDE PEROXIDE ON RESIN-DENTIN BOND STRENGTHS: A NOVEL PILOT STUDY

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This study investigates the problem of reduced composite bond strength to dentin treated with 10% carbamide peroxide gel. The authors correctly point out that exposed root surfaces are being bleached in adults and the elderly, in whom gingival recession is a common finding. The frequency of bleached root surface dentin has increased because of the popularity of dentist-dispensed and over-the-counter peroxide bleaching agents. At the same time, the need for restorations bonded to root surface dentin is also increasing. It is important that dentists learn more about this issue and that researchers discover the mechanisms of the effects of peroxide bleaching agents on tooth structure.

The effects of peroxide bleaching on the bond strength of composite to enamel is well documented, and it is prudent to wait at least 2 weeks following the final bleaching treatment before performing adhesive procedures on enamel. There is some controversy on the mechanism causing the decreased bond strength; however, residual oxygen molecules in the tooth that inhibit full polymerization of the resins largely contribute to the problem. It seems unlikely that the peroxide alters the enamel structure in any way that would cause a reduction in composite bond strength. The effects on dentin may be quite different owing to the higher organic content compared with enamel. Thirty-three percent of the total volume of dentin is organic (primarily collagen) compared with < 4% of total volume for enamel.

The research described in this article is a novel approach to evaluating the effect of 10% carbamide peroxide on composite bond strength to dentin. Third molar teeth from one subject were extracted and prepared for microtensile testing. Prior to bonding of the composite, the subject from whom the teeth were extracted wore a removable appliance for 21 days containing dentin disks cut from the extracted teeth. The subject bleached

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