Effect of nonvital bleaching with 10% carbamide peroxide on sealing ability of resin composite restorations

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Abstract

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Aim To (i) determine the effect of nonvital bleaching with 10% carbamide peroxide on the sealing ability of resin composite restorations bonded with a self-etching adhesive system; and (ii) compare the effects of antioxidant treatment and delayed restoration after bleaching on marginal seal.

Methodology Forty-eight noncarious maxillary incisors were divided into four groups ($n = 12$) after conventional root canal treatment was completed. In group 1, access cavities were restored with a self-etching adhesive system and resin composite. In the remaining three groups, 10% carbamide peroxide bleaching gel was placed into the access cavities for periods of 8 h per day for 1 week. They were then restored in the same manner as group 1. Group 2 consisted of specimens restored immediately after bleaching. Group 3 specimens were treated with the antioxidant, 10% sodium ascorbate, whereas group 4 specimens were immersed in artificial saliva for 1 week before restoration. Ten specimens in each group were then subjected to dye leakage; the remaining 2 specimens were examined in a SEM (Jeol/JSM 5200, Tokyo, Japan). The dye penetration was assessed with the standard scoring system. Statistical analysis was carried out using the Kruskal–Wallis and the Mann–Whitney tests.

Results Groups 1, 3 and 4 exhibited similar leakage patterns and significantly less leakage than group 2 ($P < 0.0083$). SEM examination of groups 1, 3 and 4 specimens demonstrated close adaptation of resin composite to cavity walls, whereas group 2 specimens did not.

Conclusion Nonvital bleaching with 10% carbamide peroxide adversely affected the immediate sealing ability of resin composite restoration; both 10% sodium ascorbate treatment and a 1-week delay in restoration following bleaching improved the reduced sealing ability of resin composite.

Keywords: adhesive resin, antioxidant, bleaching, carbamide peroxide, delayed restoration, resin composite.

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Introduction

The intracoronal application of bleaching agents has been used successfully for whitening root filled teeth. In traditional nonvital bleaching techniques, 30% hydrogen peroxide solutions have been used alone, with heat activation (thermocatalytic technique) or in combination with sodium perborate (walking bleach technique; Friedman 1997). Recently, the use of 30% hydrogen peroxide has been less favoured because of concerns over cervical external resorption (Carrillo *et al.* 1998).

In 1996, one manufacturer (Ultradent Products, South Jordan, UT, USA) suggested the use of 10% carbamide peroxide applied in a tray for a tooth prepared for the traditional walking bleach technique. This technique is called inside/outside bleaching as the bleaching takes place simultaneously within and outside the tooth (Settembrini *et al.* 1997). Several authors have reported that this technique can be successfully used for bleaching nonvital teeth (Settembrini *et al.* 1997, Carrillo *et al.* 1998, Perrine *et al.* 2000).

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Although nonvital bleaching is successful in the short term, success rate decreases with time. Within 1–5 years following bleaching, only 35–50% of teeth remain aesthetically satisfactory (Howell 1981, Feiglin 1987, Friedman *et al.* 1988). Colour regression may occur because of leakage of fluid into the bleached and restored cavity (Howell 1981, Baratieri *et al.* 1995). Furthermore, following root canal treatment, a coronal restoration that fails to provide a seal may permit the movement of microorganisms or their toxins along the canal walls or through the voids in the root filling to the periapical tissues, resulting in treatment failure (Galvan *et al.* 2002). As nonvital bleaching is followed by restoration, one of the prerequisites is that the restoration prevents microleakage. Despite the utilization of modern dentine adhesive systems, nonvital bleaching with 30% hydrogen peroxide and sodium perborate has been shown to adversely affect the sealing ability of resin composites when bonding is performed immediately following bleaching (Barkhordar *et al.* 1997, Demarco *et al.* 2001).

A number of studies have shown that the bond strength of adhesive restorations to tooth structures is reduced when the tooth has been bleached, using either an in-office technique or an at-home technique (Titley *et al.* 1992, Ben-Amar *et al.* 1995, Spyrides *et al.* 2000, Cavalli *et al.* 2001). Thus, several authors have recommended delays in restorative procedures to avoid clinical problems related to compromised bond strength following bleaching (Torneck *et al.* 1991, McGuckin *et al.* 1992, Miles *et al.* 1994, Spyrides *et al.* 2000). A recent study (Lai *et al.* 2002) has shown that carbamide peroxide-induced reduction in bond strength of resin composite to dentine is reversed with the use of the antioxidant, sodium ascorbate. The working hypotheses of the present study were: (i) nonvital bleaching with 10% carbamide peroxide would adversely affect the sealing ability of resin composite restoration; and (ii) antioxidant treatment and delayed restoration after bleaching would improve the reduced sealing ability of coronal restoration.

Materials and methods

A total of 48 freshly extracted, noncarious, single-rooted maxillary central and lateral incisors were used. Endodontic access cavities were prepared 3 mm in a diameter using a round diamond bur in a high-speed handpiece under cooling with air/water. The root canals were instrumented using conventional biomechanical techniques and filled with sealer (Diaket, 3M/ESPE, Seefeld, Germany) and gutta-percha (Hygenic, Akron, OH, USA) using a cold lateral condensation technique. The root canal filling was removed to a level 2 mm apical to the buccal cemento-enamel junction. Then, a glass ionomer base (ChemFil Superior, De Trey Dentsply, Konstanz, Germany), 2 mm thick, was placed. The teeth were divided into four groups ($n = 12$), each including four lateral and eight central incisors, which were randomly chosen for each group. The groups were then subjected to various treatments.

Group 1 (control group)

The self-etching dentine adhesive system, Clearfil SE Bond (Kuraray, Osaka, Japan), was applied to the endodontic access cavity and pulp chamber according to the manufacturer's instructions. One drop of primer was applied to the entire preparation for 20 s and gently air-dried. A layer of bonding resin was applied to the preparation with a brush, spread gently with air and cured for 10 s using an Optilux 401 visible light curing unit (Demetron, Danbury, CT, USA) with an intensity in excess of 450 mW cm^{-2}. Composite resin (Clearfil AP-X, shade A3, Kuraray) was placed and polymerized in three 1.5–2 mm thick increments. A light exposure time of 40 s was used for each increment.

Group 2 (immediate-restored group)

The teeth were mounted with the incisal edges upward in a plastic holder with a high-consistency polysiloxane impression material (Coltène Speedex Putty, Coltène AG, Altstätten, Switzerland). A 10% carbamide peroxide gel (Opalescence, Ultradent Products, South Jordan, UT, USA) was placed into the pulp chamber and access cavity so as to extend onto the lingual surface for 8 h each day. The specimens were partially immersed in artificial saliva (Cavalli *et al.* 2001) at 37 °C in a glass laboratory beaker so that bleaching gel did not contact the saliva. After completion of the daily bleaching procedure, the pulp chamber and access cavity were irrigated with 2 mL of water using a syringe and a cotton pellet was inserted into the pulp chamber. For the remaining hours in the day, specimens were stored in artificial saliva at 37 °C. The procedure was continued for 1 week. At the end of this 1-week bleaching treatment, the preparations were restored as described in group 1.

Group 3 (antioxidant-treated group)

The teeth were submitted to bleaching treatment, as in group 2. Immediately after the completion of treatment, the teeth were removed from the plastic holders, and access cavities and pulp chambers were filled with 10% sodium ascorbate using a syringe. Each tooth was placed, incisal side down, in a separate polystyrene tube (12 mm × 75 mm, Becton, Dickinson and Company, Franklin Lakes, NJ, USA) with dual-position snap cap containing 5 mL of 10% sodium ascorbate. After the tubes were incubated at 37 °C for 3 h, the teeth were removed from the tubes and rinsed with an air/water spray for 30 s and gently air-dried. Then, preparations were restored as described previously.

Group 4 (delayed-restored group)

All experimental procedures were performed exactly as in group 2, except that specimens were immersed in 250 mL of artificial saliva at 37 °C for 1 week before the placement of resin composite restoration. The artificial saliva, with an electrolyte composition similar to that human saliva, was composed of 1 g sodium carboxymethylcellulose, 4.3 g xylitol, 0.1 g potassium chloride, 0.1 g sodium chloride, 0.02 mg sodium fluoride, 5 mg magnesium chloride, 5 mg calcium chloride, 40 mg potassium phosphate, 1 mg potassium thiocyanate and 100 g distilled deionized water (Cavalli *et al.* 2001). Prior to immersion in artificial saliva, a cotton pellet was placed into the pulp chamber and the access cavity was sealed with Cavit (3M/ESPE, Seefeld, Germany). The artificial saliva was changed twice daily during the 1-week period.

All four groups of teeth were stored in distilled water at 37 °C, and restorations were finished and polished 24 h after being placed with the Enhance system (LD Caulk/Dentsply, Milford, DE, USA). They were then subjected to 500 thermal cycles between water baths of 5 and 55 °C, with a dwell time of 30 s. While 10 teeth in each group were subjected to dye leakage test, 2 teeth in each group were examined in a scanning electron microscope (SEM).

All of the teeth were covered with two coats of nail polish (Lâncome, Paris, France), except the restorations and 1 mm around them; the root apices were sealed with modelling wax (Dentsply DeTrey, Bois Colombes, France). The specimens were immersed, incisal side down, in India ink (Pelikan, Hanover, Germany) in separate sealable glass vials at 37 °C for 24 h.

After staining, teeth were washed in tap water, and nail polish and modelling wax were removed with a scalpel. The teeth were sectioned longitudinally using a low-speed diamond saw (Isomet, Buehler Ltd, Lake Bluff, IL, USA). Sections were made from buccal to lingual, through the centre of the coronal restoration and root filling. Microleakage was assessed by two calibrated examiners who were blinded to the treatment groups using a stereomicroscope (Olympus Co, Tokyo, Japan) at ×16 magnification. Each examiner judged the depth of the stain independently according to the standard ranking (Fig. 1). If the examiners achieved different scores, new readings were performed and consensus was obtained.

A nonparametric Kruskal–Wallis test was used to determine whether there were significant differences amongst the groups. Pair-wise comparisons were performed using the Mann–Whitney test with Bonferroni correction. The level of significance was primarily set as $P < 0.05$ in all tests. However, after Bonferroni correction, this level was reset as $P < 0.0083$.

For SEM examination, the teeth were sectioned mesio-distally and bucco-lingually as described above. Sectioned surfaces were treated with 35% phosphoric acid (Ultradent Products) for 10 s and rinsed with a water stream for 10 s. The specimens were then dehydrated in ascending grades of ethyl alcohol, vacuum-dried, coated with 20 nm of gold and viewed under SEM (Jeol/JSM-5200, Tokyo, Japan).

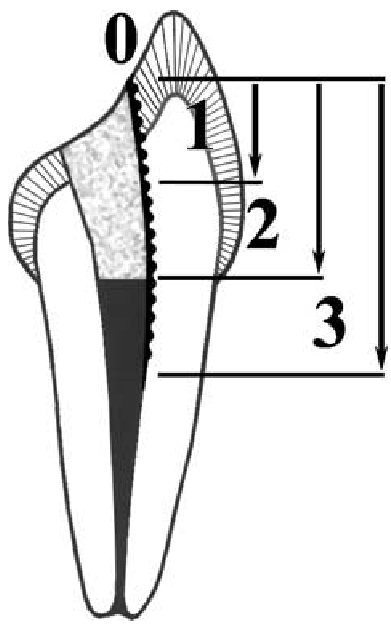

Figure 1 Microleakage scores: 0, no leakage; 1, dye penetration occurred up to half of the cavity wall depth; 2, dye penetration greater than half of the cavity wall depth; and 3, dye penetration involving the root canal filling.

Table 1 Microleakage scores obtained from the groups

	Scores			
	0	1	2	3
Group 1	7	2	1	–
Group 2	1	1	8	–
Group 3	7	3	–	–
Group 4	5	4	1	–

Results

Microleakage scores obtained from groups 1–4 are presented in Table 1. None of the specimens exhibited the highest score (3), which represents dye penetration to the root filling. There was a significant difference amongst the groups ($P < 0.05$). There was no statistically significant difference between groups 1 and 3 ($P > 0.0083$), and the specimens in these groups exhibited significantly less leakage than those in group 2 ($P < 0.0083$). Although groups 1 and 3 demonstrated less leakage than group 4, pair-wise comparisons did not show any statistical significance ($P > 0.0083$).

SEM examination of the specimens in groups 1, 3 and 4 exhibited close adaptation of the resin composite to the cavity walls (Fig. 2a,b). The specimens in group 2 showed marginal gap formation along the tooth–resin composite interface (Fig. 3a,b).

Discussion

As bleaching of root filled teeth is performed before the placement of an aesthetic restoration, increased microleakage could impair the long-term success of both the bleaching procedure and endodontic therapy (Howell 1981, Klevant & Eggink 1983, Feiglin 1987, Friedman *et al.* 1988, Ray & Trope 1995, Galvan *et al.* 2002).

Dye penetration has remained a popular leakage test, and India ink is a commonly used tracer in such studies (Wu & Wesselink 1993, Chong *et al.* 1995, Howdle *et al.* 2002). In this study, microleakage was investigated using a dye leakage model with India ink. Chong *et al.* (1995) noted that bacterial ingress and India ink penetration provided a similar rank order for the sealing ability of the materials tested. India ink has been shown to consist of a range of particle sizes between 0.5 and 600 μm in diameter. Approximately 8% of the particles were smaller than 1.60 μm (Youngson *et al.* 1998). As dentinal tubules have an average diameter of 1.65 μm (Pashley 1989), these particles are capable of entering tubules. Also, approximately 57% of the particles were below 20.90 μm (Youngson *et al.* 1998). Therefore, they would be able to penetrate cervical contraction gaps (7–22 μm) observed *in vitro* (Torstenson & Brännström 1988). Youngson *et al.* (1998) reported that India ink staining tended to appear less intense than that of other tracers such as eosin, methylene blue and silver nitrate. This might have been because of the small percentage of particles within India ink, which were small enough to enter dentinal tubules. Furthermore, they suggested that the decreased tendency of ink to enter dentine might be of benefit as it could decrease the problem of differentiating true leakage from dentinal permeability (Youngson *et al.* 1998). A significant limitation in this study is the use of a longitudinal midline section to assess the depth of dye penetration, whereas the use of serial sections to give a more comprehensive picture has been described by Youngson (1992). The midline section, however, is widely used within the research field and may provide a 'worst case analysis' of dentine penetration as it allows visualization of what is usually the deepest aspect of a cavity and is therefore associated with the most permeable dentine (Youngson *et al.* 1998).

In this study, a self-etching primer adhesive, Clearfil SE Bond, was used for bonding the resin composite restoration. Recently, the use of self-etching primer adhesive systems has gained wider acceptance by the profession, as they are less technique sensitive. These systems do not require separate etching, rinsing and drying procedures, and thus eliminate the risk of over-etching and over-drying (Van Meerbeek *et al.* 1998, Kubo *et al.* 2001). A number of studies have reported that the self-etching primer adhesive systems, including Clearfil SE Bond, have prevented microleakage (Kubo *et al.* 2001, Sengün *et al.* 2002, Yazici *et al.* 2002).

The results of this study demonstrated that nonvital bleaching with 10% carbamide peroxide had an adverse effect on the sealing ability of resin composite restoration when the bonding procedure was performed immediately after bleaching. These findings are in agreement with those of several published reports on the deleterious effect of carbamide peroxide on the bond strength of resin composite to enamel and dentine (Stokes *et al.* 1992, Titley *et al.* 1992, Ben-Amar *et al.* 1995, Sung *et al.* 1999, Spyrides *et al.* 2000, Cavalli *et al.* 2001). Previous microleakage studies have also shown that the walking bleach technique has an adverse effect on the seal at the tooth-restoration interface (Barkhordar *et al.* 1997, Demarco *et al.* 2001). While hydrogen peroxide has been utilized in those studies, carbamide peroxide used in the present study breaks down intraorally into urea and hydrogen peroxide. Thus, the findings obtained in hydrogen peroxide studies may also be applicable for

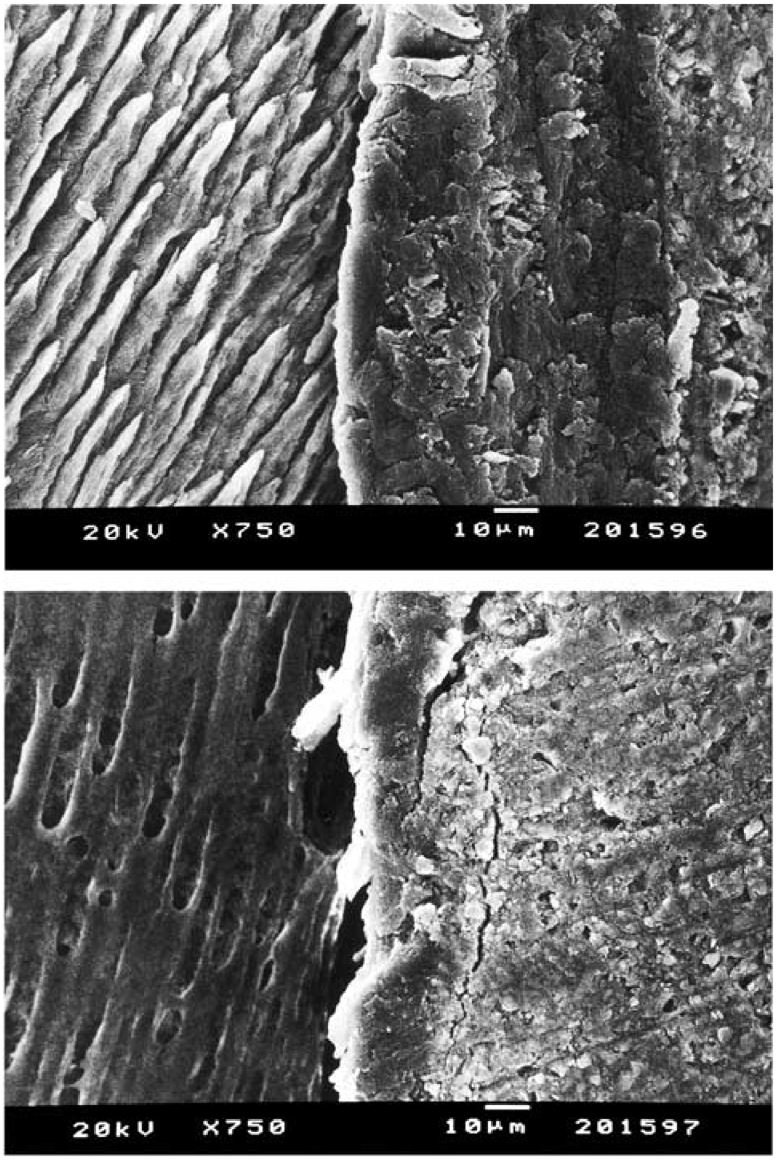

Figure 2 SEM photograph of the specimen from the antioxidant-treated group: (a) no gap formation along the enamel–resin composite interface (magnification ×750); (b) close adaptation of resin composite to cavity wall in dentine (magnification ×750).

those using carbamide peroxide. Contrary to the findings of this study, Crim (1992) demonstrated no significant difference in microleakage between teeth having been exposed to carbamide peroxide for 54 h and the nonbleached controls. In that study, cavity preparation was carried out following the completion of bleaching. Thus, the bleached enamel surfaces that would adversely affect the sealing ability of resin composite restoration have been removed. In a previous study, Cvitko *et al.* (1991) suggested that removing superficial enamel after bleaching restored the bond strengths to normal levels. In the present study, cavity preparation was completed before bleaching procedures and no further preparation was carried out prior to the placement of the resin composite restoration.

A number of studies have examined the physical changes in enamel after bleaching in order to provide a possible explanation for the decrease in the bond strength caused by carbamide peroxide. Several authors have suggested that the poor bonding surfaces are created by changes in enamel structure resulting from increased porosity manifesting itself with an over-

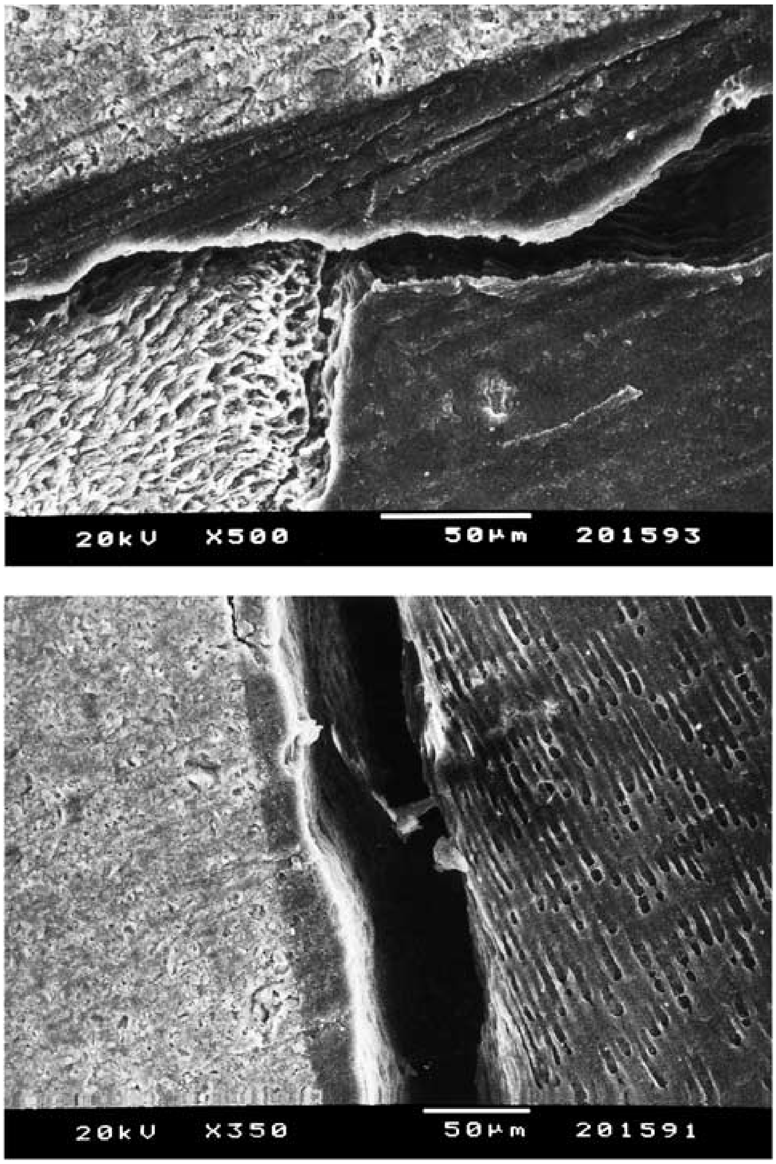

Figure 3 SEM photograph of the specimen from the immediate-restored group: (a) poor adaptation of resin composite to cavity wall in both enamel and dentine (magnification ×500); (b) wide gap formation along the dentine–resin composite interface (magnification ×500).

etched appearance and loss of prismatic form (Ben-Amar *et al*. 1995, Josey *et al*. 1996). In addition, loss of calcium, decrease in microhardness and alterations in the organic substance might be important factors causing a decrease in enamel bond strengths (McCracken & Haywood 1996, Hegedüs *et al*. 1999).

Another explanation for the increase in microleakage could be the residual peroxide from the bleaching agent, which interferes with resin attachment and inhibits resin polymerization (Ruyter 1981). In a previous study, the reduction in adhesiveness of carbamide peroxide-bleached enamel was explained on the basis of the interaction between resin and residual peroxide that occurred at the resin composite–enamel interface (Titley *et al*. 1992). SEM examination of the resin composite–enamel interface demonstrated a granular and porous appearance with a bubbled appearance.

The present study has shown that immersion of bleached specimens in artificial saliva for 1 week increased the sealing ability of resin composite restorations, but not up to the levels obtained in the control group. However, previous studies have shown that a 1-week immersion of bleached specimens in distilled water resulted in a complete reversal of the reduced enamel bond to resin composites (Torneck *et al.* 1991, McGuckin *et al.* 1992, Miles *et al.* 1994). It has been suggested that during the post-bleaching stage before bonding, elimination of residual peroxide can be achieved by leaching in water and had been expected that under clinical conditions, saliva could have a similar action after bleaching. In the previous studies, bleached surfaces were directly in contact with distilled water. However, in the present study, the pulp chamber and the access cavity where the bleaching gel had been placed were sealed before immersion in artificial saliva. This may retard the elimination of residual peroxide from the tooth structure. Furthermore, some authors have suggested that post bleaching periods longer than 1 week before bonding are needed in order to restore the reduced enamel bond strength (Van der Vyder *et al.* 1997, Cavalli *et al.* 2001). Spyrides *et al.* (2000) also reported that a 1-week delay in bonding might not be sufficient to restore the reduced bond strength of bleached dentine with 10% carbamide peroxide. Therefore, they have speculated that the effect of bleaching on dentine might be more permanent or take longer to eliminate.

Ascorbic acid and its salts are well-known antioxidants and are capable of reducing a variety of oxidative compounds, especially free radicals (Buettner 1993, Rose & Bode 1993). Previous studies have demonstrated the potential protective effect of ascorbic acid *in vivo* against hydrogen peroxide-induced damage in biological systems (Smit & Anderson 1992, Brennan *et al.* 2000). In the present study, treatment of the pulp chamber and access cavity with 10% sodium ascorbate before bonding appeared to restore the sealing ability of resin composite restoration. These results concur with those of Lai *et al.* (2002) who reported that reduced bond strength of resin composite to bleached enamel was effectively reversed by antioxidant treatment. They also reported that under transmission electron microscopy, enamel bleached with 10% carbamide peroxide demonstrated an extensive etching pattern and bubble-like structures. In their study, a mild etching pattern was observed in the bleached but ascorbate-treated enamel, whereas the abnormal bubble-like structures were not. Lai *et al.* (2002) immersed the bleached specimens in 10% sodium ascorbate solution for 3 h. Although the 3-h use of sodium ascorbate is not practical in clinical use, the duration of antioxidant treatment was determined to be 3 h in the present study as well. Further studies are required to determine the minimal time necessary for antioxidant treatment of access cavity after nonvital bleaching. If a time shorter than 3 h is not found to be sufficient, incorporating sodium ascorbate into a gel would be advantageous in its intraoral use for a long time. A gel containing sodium ascorbate could be used by patients, after completion of the bleaching treatment by placing it into the bleaching tray.

In this study, observations obtained during SEM examination supported the results of the dye leakage test. The specimens in the control, delayed-restored and antioxidant-treated groups exhibited close adaptation of resin composite to the cavity walls. However, the specimens in the immediate-restored group exhibited gap formation along the tooth and resin composite interface.

In the intracoronal bleaching procedures, placement of a glass ionomer base over the root filling is an important step to seal the root canal from the bleaching agent. In this study, dye leakage did not reach the root filling in any of the specimens, even in the immediate restored group after bleaching, in which coronal microleakage was more severe than in the other groups. This may be because of the glass ionomer base, which may have acted as a barrier against the coronal microleakage. In a review of the experimental evidence, Saunders & Saunders (1994) have concluded that the floor of the pulp chamber should be covered with a lining of glass ionomer after removing excess gutta-percha and sealer. Previous studies have also showed the advantages of the placement of a glass ionomer base over the gutta-percha to prevent coronal microleakage (Carmen & Wallace 1994, Barthel *et al.* 1999).

Conclusions

1 Nonvital bleaching with 10% carbamide peroxide adversely affected the sealing ability of resin composite restorations when the bonding procedure was performed immediately after bleaching.
2 Treatment of access cavities and pulp chambers with 10% sodium ascorbate for 3 h following bleaching restored the sealing ability of resin composite.
3 One-week delay in restorative procedures after bleaching improved the reduced sealing ability of resin composite, but did not reverse it entirely.

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