Can intracoronally bleached teeth be bonded safely?

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Introduction: Our objective was to determine the effects of intracoronal bleaching on the shear bond strength and failure side location of metallic brackets at 2 times (bleaching immediately before bonding and 30 days before bonding). Methods: Sixty freshly extracted mandibular incisors were randomly divided into 3 groups; each group contained 20 teeth. After finishing canal preparation and root canal filling, the root fillings were removed to a level 2 mm apical to the cementoenamel junction. Glass ionomer base (Vitrabond, 3 M Dental Products, St Paul, Minn) was placed approximately 2-mm thick. Bleaching agent (Whiteness Perfect, FGM Dental Products, Joinville, Brazil) was placed into the rest of the cavity for 4 days at 2 times. Shear bond strength of these brackets was measured in megapascals. The adhesive remnant index (ARI) scores were determined after the brackets failed. Data were analyzed with analysis of variance (ANOVA), Tukey, and chi-square tests.

Results: The bond strengths of the group with no bleaching (mean, 20.25 ± 7.06 MPa) were significantly higher (P < 0.001) than those of the group that had bleaching immediately before bonding (mean, 4.85 ± 3.22 MPa) and the group that had bleaching 30 days before bonding (mean, 8.70 ± 4.93 MPa). The results of the chi-square comparisons indicated significant differences among the 3 groups. In the group with no bleaching, there was a higher frequency of ARI scores of 2 to 4, indicating cohesive failures in the resin. In the other 2 groups, the failures were mostly adhesive at the resin-enamel interface (ARI scores of 4 and 5).

Conclusions: Intracoronal bleaching with carbamide peroxide adversely affected the shear bond strength and changed the site of failure during debonding when bonding was done immediately or 30 days after bleaching. (Am J Orthod Dentofacial Orthop 2009;136:689-94)

Discolored teeth, especially in the anterior region, can cause considerable cosmetic impairment. When the pulp is injured, blood extravasations from ruptured vessels can invade the pulp chamber, and erythrocytes can penetrate the dentinal tubules. The erythrocytes undergo hemolysis and liberate hemoglobin; this releases iron. The iron is combined with hydrogen sulfide to form iron sulfide, a black compound that gives teeth the dark discoloration.

In addition to invasive therapies, such as crowning or veneers, whitening of teeth is an alternative therapeutic method. The discoloration of teeth with nonvital pulp requires an effective treatment with chemical bleaching agents. This chemical bleaching can be achieved with both extracoronal and intracoronal bleaching techniques.

Based on clinical experience and research, extracoronal tooth bleaching is considered safe and effective, and the most conservative method of improving the esthetics of discolored teeth. However, several studies reported that extracoronal bleaching has some disadvantages, including tooth sensitivity, gingival irritation, and recurrent discoloration after bleaching. In addition, alterations in enamel surface morphology and reductions in bond strength of adhesives after bleaching have been reported. These adverse effects are clinically critical when bonding resin composites, porcelain veneers, and orthodontic brackets to bleached enamel surfaces.

Previous studies have shown a change in enamel structure, composition, and bond strength when exposed to the bleaching agents used for extracoronal bleaching. Torneck et al identified a substantial reduction in bond strength to enamel shortly after its exposure to concentrated aqueous solutions of a bleaching agent. In addition, intracoronal (nonvital, devital) bleaching has been found to reduce the microhardness of dentin and enamel and weaken the mechanical properties of the tooth structures.
showed a relationship between the microhardness and calcium concentration and bond strength.

In restorative dentistry, several studies have evaluated the shear bond strength of composite resins on enamel and dentin after intracoronal bleaching, but there is no consensus on its effects on bond strength. Some studies showed that the bonding strength of enamel decreases after intracoronal bleaching with carbamide peroxide in various concentrations, and some concluded that permanent restoration can be accomplished safely immediately after intracoronal bleaching.

In the orthodontic literature, various study designs were used to evaluate the effect of extracoronal (vital) bleaching on the bond strength of orthodontic brackets. Cacciafesta et al evaluated the effects of bleaching on the bond strength values of resin-modified glass ionomer cements and found that bleaching before bonding significantly lowered the bond strength of the resin-modified glass ionomer, Fuji Ortho LC. In a recent study, Uysal and Sisman found that the use of a carbamide peroxide bleaching agent immediately before bonding significantly reduced the shear bond strength values of orthodontic self-etching primer systems.

Since some adults who are interested in orthodontic treatment might have also had their endodontically treated teeth bleached or might want bleaching, it seems important to determine whether this procedure would significantly influence the bonding strength of orthodontic bracket adhesives to the enamel surface.

So far, to our knowledge, no studies have investigated the effect of intracoronal bleaching on the bond strength values of metallic brackets.

The purpose of this in-vitro study was to determine the effects of intracoronal bleaching on the shear bond strength and the adhesive remnant index (ARI) scores of metallic brackets at 2 times (bleaching immediately before bonding and 30 days before bonding). The null hypotheses to be tested were that there are no statistically significant differences in (1) bond strength and (2) failure site locations of intracoronal bleached and unbleached teeth at the 2 times.

**MATERIAL AND METHODS**

Sixty noncarious freshly extracted single-rooted mandibular incisors were used in this study. Teeth with hypoplastic areas, cracks, or gross irregularities of the enamel structure were excluded. The criteria for tooth selection dictated no pretreatment with a chemical agent such as alcohol, formalin, or hydrogen peroxide, or any other form of bleaching. Immediately after extraction, the teeth were scraped of any residual tissue tags and washed under running tap water. The teeth were stored in distilled water, and the water was changed weekly to prevent bacterial growth. The teeth were randomly divided into 3 groups of 20 teeth each. All teeth were mounted vertically in self-cure acrylic so that the crowns were exposed. The buccal surfaces were cleaned and polished with a rubber cup and slurry with pumice and water, followed by rinsing with water spray and drying with compressed air.

Endodontic access cavities were prepared with ISO (International Organisation of Standardization) 12 round diamond bur (Diatech, Coltene Whaledent, Altstätten, Switzerland) with a high-speed handpiece under water cooling. The root canals were made by using Protaper nickel-titanium rotary instruments (Dentsply-Maillefer, Ballaigues, Switzerland), and 1 mL of 2.5% sodium hypochloride irrigation was provided between each file. Final irrigation was applied with saline solution, and the root canals were dried with sterile paper points. The canals were filled with an epoxy-resin root canal sealer AH 26 (Dentsply, De Trey, Konstanz, Germany) and gutta-percha (SPI Dental, Inchon, Korea) by using a cold lateral condensation technique. Then the root fillings were removed 2 mm apical to the cementoenamel junction. Light-cured glass ionomer base (Vitrabond, 3M Dental Products, St Paul, Minn) was placed approximately 2 mm thick. All specimens for bracket bonding were prepared with 1 of the following procedures.

Group A (control): the access cavity was rinsed with distilled water and dried, and final composite restoration was finished. A 37% phosphoric acid gel (3M Dental Products) was used for the acid etching of the 20 incisors for 30 seconds. The teeth were then rinsed with water from a 3-in-1 syringe for 30 seconds and dried with an oil-free source for 20 seconds.

Group B: intracoronal bleaching was performed according to the manufacturer’s instructions. The bleaching agent (16% carbamide peroxide, Whiteness Perfect, FGM Dental Products, Joinville, Brazil) was placed into the rest of the cavity and closed by a temporary filling material (Cavit, AG, D-82229, 3M ESPE, Seefeld, Germany). After 4 days, this procedure was repeated to simulate the clinical conditions when 1 more bleaching sequence is needed. After 4 days, the temporary filling material was removed, and, to neutralize the bleaching agent, calcium hydroxide was placed for 1 more week. Then the access cavity was rinsed with distilled water, and final composite restoration was placed. The bracket bonding area was etched with 37% phosphoric acid gel for 30 seconds.

Group C: this group was treated the same as group B, except that, after bleaching and before etching, the teeth were stored in artificial saliva for 30 days at room temperature. The artificial saliva was changed daily.
Sixty stainless steel mandibular incisor brackets (3M Unitek, Monrovia, Calif) with a base surface area of 6.82 mm² were used in all groups. The mean base surface area of the brackets was calculated by measuring the length and width and computing the area. After surface preparation, liquid primer of the Transbond XT (3M Unitek) was applied to the etched surface, and the brackets were bonded on the incisors with Transbond XT; any excess resin was removed with an explorer before the resin was polymerized. Then a light-emitting diode (Elipar Freelight 2, 3M ESPE) was used for curing the specimens for 20 seconds.

After these procedures, the embedded specimens were secured in a jig attached to the base plate of a universal testing machine (Hounsfield Test Equipment, Salfords, United Kingdom). A chisel-edge plunger was mounted in the movable crosshead of the testing machine and positioned so that the leading edge was aimed at the enamel-adhesive interface. A crosshead speed of 0.5 mm per minute was used, and the maximum load necessary to debond the bracket was recorded. The force required to remove the brackets was measured in newtons (N), and the shear bond strength (1 MPa = 1 N/mm²) was calculated by dividing the force values by the bracket base area (6.82 mm²).

After debonding, all teeth and brackets were examined under 10-times magnification. Any adhesive remaining after bracket removal was assessed with the ARI and scored according to the amount of resin adhering to the enamel surface. The ARI scale has a range between 5 and 1: 5 indicates that no composite remained on the enamel; 4, less than 10% of the composite remained on the tooth; 3, more than 10% but less than 90% remained on the tooth; 2, more than 90% of the composite remained; and 1, all composite remained on the tooth, with the impression of the bracket base.

**Statistical analysis**

All statistical analyses were performed with Statistical Package for Social Sciences software (SPSS for Windows, version 10.0.1, SPSS, Chicago, Ill). Descriptive statistics, including means, standard deviations, and minimum and maximum values were calculated for the 3 groups of teeth. Comparisons of the means of the shear bond strength values were made with analysis of variance (ANOVA). Multiple comparisons were done by Tukey tests. The chi-square test was used to determine significant differences in the ARI scores among the 3 groups.

**RESULTS**

The descriptive statistics for the shear bond strengths of the groups are presented in Table I. The results of ANOVA indicated statistically significant differences among the 3 groups (F = 45.579, P = 0.000). Thus, the first null hypothesis of this study was rejected. The Tukey test showed that the bond strengths of group A (no bleaching; mean, 20.25 ± 7.06 MPa) was significantly higher (P > 0.001) than those of group B (bleaching immediately before bonding; mean, 4.85 ± 3.22 MPa) and group C (bleaching 30 days before bonding; mean, 8.70 ± 4.93 MPa). We found no statistically significant differences between groups B and C (P = 0.065).

The ARI scores for the various groups tested are listed in Table II. The results of the chi-square comparisons indicated significant differences among the 3 groups (chi-square = 34.468, P = 0.000). Therefore, the second null hypothesis of this study was rejected. In group A, there was a higher frequency of ARI scores of 2 through 4, indicating cohesive failures in the resin. In groups B and C, the failures were mostly adhesive at the resin-enamel interface (ARI scores of 4 and 5).

**DISCUSSION**

Esthetics of the teeth including color are of great importance to patients. Orthodontists often face patients who are dissatisfied not only with the appearance, but also with the color, of their teeth. A number of methods and approaches have been described for bleaching teeth. These methods have various bleaching agents, concentrations, times of application, product format, application mode, and light activation. In the orthodontic literature, different concentrations and bleaching agents were investigated with the extracoronal bleaching method related to shear bond strength of orthodontic brackets. Some authors investigated the effect of 25% to 35% hydrogen peroxide on the shear bond strength of brackets bonded on the bleached enamel, and some used 10% carbamide peroxide. In restorative dentistry, many studies have investigated the effect of intracoronal bleaching on resin-enamel and resin-dentin shear bond strength. However, a review

![Table I. Descriptive statistics and results of ANOVA comparing shear bond strength of 3 groups](image-url)
of the literature indicated no studies on the effect of intracoronal bleaching treatment on the bond strength of metallic brackets bonded with orthodontic composites to enamel.

Several authors reported significant decreases in the bond strength of composite resin to carbamide peroxide bleached enamel compared with unbleached enamel. Most reports have evaluated the physical changes in enamel after bleaching to provide a possible explanation for the decreased bond strength caused by bleaching agents. Some studies suggested that the lower bond strengths are created by the changes in enamel structure resulting from increased porosity manifesting as an overetched appearance and loss of prismatic form. In addition, Lewinstein et al indicated that intracoronal bleaching reduces the microhardness of dentin and enamel by the loss of calcium and alterations in the organic substance, and these factors might be important to cause decreased enamel bond strengths. Another study showed a relationship between microhardness and calcium concentration and bond strength. Consistent with these previous explanations, the results of our study demonstrated a statistically significant reduction in shear bond strength of brackets for teeth bonded immediately after intracoronal bleaching compared with the control group.

It was proposed that residual oxygen from the bleaching agent interferes with resin attachment and inhibits resin polymerization. Although there are remarkable variations among the recommended post-bleaching times in different studies (24 hours-4 weeks), some authors thought that a delay of at least 2 weeks is needed after bleaching for the tooth structure to regain its prebleaching adhesive properties. Uysal et al and Uysal and Sisman stored their samples in artificial saliva for 30 days and suggested that a delay of bonding for a minimum of 2 to 3 weeks might be beneficial. Spyrides et al also reported that a 1-week delay in bonding might not be sufficient to restore the reduced bond strength of bleached structures. Therefore, they speculated that the effect of bleaching might be more permanent or take longer to eliminate. In the previous studies, bleached surfaces were directly in contact with distilled water or artificial saliva. However, in our study, the pulp chamber and the access cavity where the bleaching gel was placed were sealed before immersion in artificial saliva. We thought that this might retard the elimination of residual peroxide from the tooth structure. We found that immersion of bleached specimens in artificial saliva for 30 days increased the shear bond strength of orthodontic brackets but not up to the levels of the control group. We found similar bond strength values with bonding immediately after bleaching and statistically significant lower values than the control.

Treating the bleached enamel surface with antioxidants (10% sodium ascorbate) before bonding reverses the reduction in bond strength of composite resin, and it might be an alternative to waiting and eliminate the need to postpone bonding.

Some researchers indicated that tooth crown fractures have also been observed after intracoronal bleaching, most probably due to extensive removal of the intracoronal dentin. However, in our study, no enamel fracture was observed during testing.

Reynolds suggested that the minimum bond strength of 5.9 to 7.8 MPa is adequate for most clinical orthodontic needs and routine clinical use. Most brackets in group C actually met those minimum bond strength requirements. Although higher failure rates were expected, the bond strength was significantly reduced but the strength was sufficient for clinical bonding. However, clinical conditions might significantly differ from an in-vitro setting. This was an in-vitro study, and the test conditions were not like the rigors of the oral environment. Heat and humidity in the oral cavity are highly variable. Because of the differences between in-vivo and in-vitro conditions, a direct comparison cannot be made with the findings of the other studies.

Table II. Frequency of distribution and comparisons of ARI scores (%)

<table>
<thead>
<tr>
<th>Group</th>
<th>1 (0%)</th>
<th>2 (50%)</th>
<th>3 (30%)</th>
<th>4 (20%)</th>
<th>5 (0%)</th>
<th>n</th>
<th>Multiple comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (control)</td>
<td>0 (0%)</td>
<td>10 (50%)</td>
<td>6 (30%)</td>
<td>4 (20%)</td>
<td>0 (0%)</td>
<td>20</td>
<td>††</td>
</tr>
<tr>
<td>B (BO)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>10 (50%)</td>
<td>10 (50%)</td>
<td>20</td>
<td>NS</td>
</tr>
<tr>
<td>C (B30)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>5 (25%)</td>
<td>15 (75%)</td>
<td>20</td>
<td>NS</td>
</tr>
</tbody>
</table>

BO, Bonded immediately after bleaching; B30, bonded 30 days after bleaching; NS, Not significant.

*ARI scores: 1, all composite, with impression of bracket base, remained on tooth; 2, more than 90% of composite remained on bracket base; 3, more than 10% but less than 90% of composite remained on tooth; 4, less than 10% of composite remained on tooth surface; 5, no composite on tooth; † P <0.001.
In the literature, 3 similar investigations evaluated the ARI scores. Some authors\textsuperscript{22,23} showed a prevalence of cohesive characteristics, but failures occurred at the enamel-adhesive interface in 1 study.\textsuperscript{26} The results of the ARI score comparisons in our study indicated significant differences among the 3 groups. In group A, there was a higher frequency of ARI scores of 2 through 4, indicating cohesive failures in the resin. In groups B and C, the failures were mostly showed adhesive (resin-enamel interface) characteristics. Failures in the bleached groups were mostly located at the adhesive-enamel interface. Therefore, we concluded that the adhesive bond strength values for bleached enamel in our study are more likely to be accurate.

CONCLUSIONS

1. Intracoronal bleaching with carbamide peroxide adversely affected the shear bond strength of orthodontic brackets when the bonding procedure was performed immediately after bleaching.
2. A 30-day delay in bonding procedures after bleaching slightly improved the bond strength of orthodontic brackets but not up to the levels of the unbleached group.
3. Bonding after intracoronal bleaching significantly alters the sites of failure during debonding. Failures in the bleached groups were mostly located at the adhesive-enamel interface.

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REFERENCES


