SCIENTIFIC SECTION

The effect of tooth bleaching on the enamel surface and the tensile force to debond orthodontic brackets

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Objective: The aim of this study was to evaluate the influence of successive tooth bleaching on the tensile force to debond orthodontic brackets and dental enamel.

Design: *In vitro* study.

Settings: Department of Orthodontics, Faculty of Dentistry, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil.

Materials and methods: Seventy-two human premolars were divided into three groups: Group 1 was not submitted to bleaching, Group 2 was subjected to one tooth bleaching (35% hydrogen peroxide enabled by LEDs) and Group 3 was subjected to two tooth bleachings interspersed by aging. Twenty teeth from each group were subjected to tensile test, failure pattern after debonding and evaluation of resin/enamel interface. Four teeth from each group were not submitted to tensile bond testing and had their external surfaces and internal structure analyzed by SEM and polarized light microscopy.

Results: The strength of the brackets decreased in Groups 2 and 3, but was not significant ($P=0.635$). In general, the failure pattern appeared at the resin/bracket interface or within the resin. The experimental groups showed an increase in slots and erosions on the surface of the enamel and were more pronounced in Group 3. There were no changes to the internal structure of the enamel.

Conclusions: The use of a 35% hydrogen peroxide in-office bleaching system, *in vitro*, seven days before bonding, does not significantly reduce the tensile force to debond orthodontic brackets, even after a second bleaching procedure. In most cases, debonding occurred at the adhesive/bracket interface or within the adhesive. Bleaching alters the enamel surface and the resin/enamel interface, but it does not influence bond strength.

Key words: Tooth bleaching, bond strength, orthodontic brackets, enamel structure, aging of tooth

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Introduction

With the growing awareness of aesthetic treatments, there is a great demand for solutions to problems such as food stains, fluorosis and the tetracycline staining of the teeth.[1–3] The advent of vital bleaching has captured the imagination of the public and the dental profession by offering the option of a non-invasive and relatively simple procedure to produce a whiter, more attractive smile.[2,4–8] Various whitening systems have been developed, and peroxide compounds at different concentrations are currently used to bleach tooth enamel.[9,10] Tooth bleaching systems today have hydrogen peroxide as the active agent.[11,12] Vital tooth bleaching can be performed at home and in-office; the latter is often used in combination with an activating agent such as heat or light.[7,11,13] The peroxide permeates the enamel and thus produces a lightening effect.[3,14]

There have been controversial reports regarding the effect of bleaching agents on the bond strength of composite materials. Some studies have shown that the bond strength of adhesive restorations and resin-bonded brackets is reduced when the tooth has been bleached with an in-office or at-home technique.[2,5,15–19] However, others studies found no significant difference between bleached and unbleached enamel with respect to composite bond strength.[1,20,21]

Bleached teeth gradually return to the original discoloration over time.[10,22] Haywood and Haymann[10] reported that bleached teeth may regress within two to three years, thus requiring retreatment. In a two-year follow-up, Dahl and Pallesen[11] revealed that teeth, on

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average, darkened by two units of a shade guide, and that regression occurred mostly during the first six months after bleaching. This darkening could have been leading patients to request successive re-bleaching.

Whitening products can be used before or after orthodontic treatment.[2] Because some adults who are considering orthodontic treatment might also have had their teeth bleached or might be interested in bleaching, it seems important to determine whether successive bleaching would significantly influence the bond strength of orthodontic bracket adhesives to the enamel surface.[21]

The purpose this study was to determine the effect of successive bleaching with a 35% hydrogen peroxide bleaching agent on the tensile force to debond metallic orthodontic brackets, and to examine the effect of bleaching on the enamel surface.

Material and method

Preparation of specimens

Seventy-two sound human upper first premolars (extracted for orthodontic reasons) were donated by the Federal University of Rio de Janeiro Dental School Tooth Bank. The experiment was approved by the ethics committee of the University (Comitê da Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro – Reference Number E-26/170.400/2006). The criteria for tooth selection were: intact buccal enamel, no pretreatment with chemical agents such as derivatives of peroxide, acid, or alcohol, no cavities, no cracks from forceps and no restorations. After extraction, the soft tissues and residue on the teeth were removed and washed. They were then stored in a solution of 0.5% thymol and kept at a temperature of 4°C. Before the experiment, all teeth were washed with water, and were stored in artificial saliva for seven days.

The samples were randomly divided into three groups of 24 teeth as follows: Group 1: control, Group 2: one bleaching process and Group 3: two bleaching processes. Specimens in the control group were not bleached. The samples in Group 3 were aged between the bleaching procedures.

The tooth crowns were separated from the roots, and the coronal pulps were removed. Seventy-two crowns were then embedded in PVC rings (Tigre S/A, Brazil) using colorless auto-cured acrylic resin (Clássico, Brazil) with the buccal surface exposed (Figure 1).

Each buccal crown surface was pumiced with a rubber prophylaxis cup (Viking, Brazil) in a low-speed conventional handpiece (Kavo do Brasil S.A. Indústria e Comércio, Brazil), washed for 10 s and dried with a mild continuous stream of oil-free compressed air.

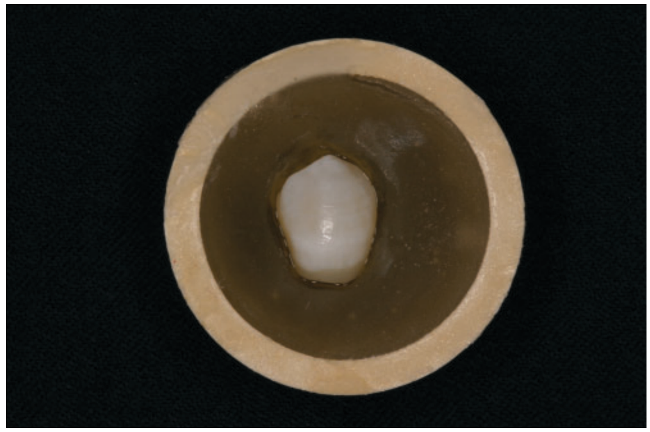


Figure 1 Tooth included in PVC ring

Bleaching and aging procedures

Teeth of Group 2 were bleached with a 35% hydrogen peroxide activated with light emitting diodes (LEDs), according to the protocol of Zanin and Brugnera Jr.[23] Briefly, the buccal surface of each tooth was cleaned as previously described. The 35% hydrogen peroxide solution and the gel were mixed and applied with a disposable brush (Technew Indústria e Comércio Ltda, Brazil) onto the buccal surface of each crown, with a layer approximately 2 mm thick. The mixture on the tooth surface was then activated with LEDs (LEC 470II, MM optical, Brazil) for 30 s. The distance between the light source and the tooth surface was set at 5 mm. After standing for 5 min, the solution was removed with water-embedded cotton, and the procedure was repeated according to the manufacturer's instructions. The teeth were rinsed with water, dried, and stored in artificial saliva for 7 days at 34°C.

The specimens in Group 3 were submitted to the same treatment as Group 2. Then the specimens of Group 3 received an aging step consisting of treatment with an ultraviolet irradiation lamp with a tungsten filament and mercury vapor atmosphere.[24] The teeth were maintained inside the apparatus at 45°C and 65% relative humidity for 24 h (ADA's Norm n.27; 1 Dentsply Trade and Industry Ltda - Brazil). This procedure is equivalent to five natural aging years (ISSO 3336-1977). The samples were placed in artificial saliva for seven days at 34°C. The bleaching procedure previously described was repeated for the second bleaching session.

Evaluation of bleaching on bond strength

Sixty teeth included in PVC rings were used in these tests.

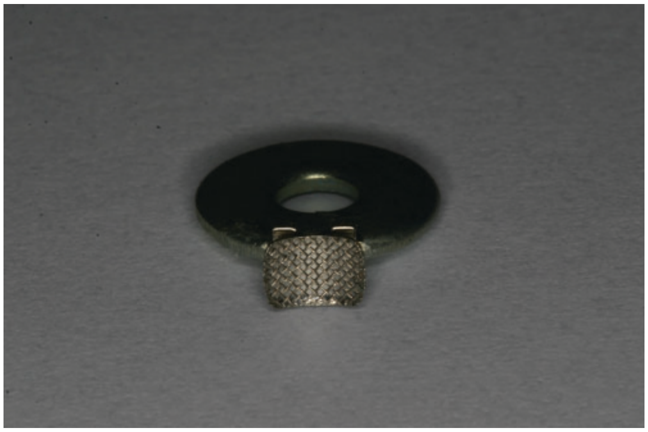


Figure 2 Metal O-ring soldered into the slot bracket

Determination of tensile force to debond orthodontic brackets

Stainless steel standard edgewise twin premolar brackets (American Orthodontics – USA, model 393-9027, slot 0.022 inches) were used in this study. To prevent deformation of the bracket base during the test, metal O-rings were previously soldered into the bracket slots (Figure 2). The 60 teeth included in the rings received prophylaxis again. The buccal surface of the tooth was etched with 37% phosphoric acid gel for 30 s, washed and dried for 20 s. After surface preparation, the liquid primer Transbond XT (3M Unitek, USA) was applied to the etched surface, and brackets were bonded on premolars with Transbond XT (3M Unitek, USA). Excess resin was removed before activation with LEDs (LEC 470II, MM Optical, Brazil) for 20 s on each face. After bonding, the samples were stored in artificial saliva for seven days at 34°C.

The tensile bond strength of the tooth was measured with a universal testing machine (DL 10000, EMIC, Brazil). The samples were clamped and aligned in the machine. The bracket slot was perpendicular to the plunger of the testing machine and crosshead speed of the 10 kg load cell was set at 1 mm min^{-1}. The load was recorded and the data for applied loads was expressed in Newton (N).

Residual adhesive. A stereo microscope at ×16 magnification was used to analyze the bonded enamel surfaces and bracket bases. The adhesive remnant index (ARI) was used to classify the failure patterns observed in debonded specimens.[25]

Scanning electron microscopy (SEM). Six teeth (two from each group), randomly chosen from samples submitted to the tensile bond strength test, were sectioned longitudinally for analysis of the resin/enamel interface. The specimens were dehydrated at room temperature, sputter-coated with gold (Balzers, Union, Germany), and then mounted on aluminum stubs for SEM analysis (JSM-5800LV, Jeol, Japan). Representative images were captured digitally and stored in computer files.

Evaluation of bleaching effect on enamel surface

Twelve teeth not included in the tensile bonding test were used for the analysis of the tooth enamel after bleaching.

Scanning electron microscopy (SEM). These teeth were sectioned longitudinally for analysis of the buccal enamel surface by SEM as previously described.

Light microscopy. The teeth were embedded in resin for hard tissue sectioning with a low speed diamond wheel saw (South Bay Technology, Inc., USA). The crowns of the teeth were sectioned longitudinally. The slices were eroded to a thickness of 100 μm with a polish machine (APL-2, Arotec, Brazil) and mounted on glass slides for examination using polarized light microscopy at magnifications of 2.5, 10 and 40×.

Statistical analysis

The tensile bond strength data were subjected to a normality test. Because the data did not have a normal distribution, a survival analysis (Kaplan-Meier) was used to determine significance between the groups. The level of significance was established as $P<0.05$. Statistical analyses were performed with the SPSS 13.0 software system (SPSS Inc., Chicago, IL, USA).

Results

Evaluation of bleaching on bond strength

Bond strength. Tensile forces to debond are shown in Newtons (N). Mean, quartiles, median and standard deviation (SD) for the groups are shown in Figure 3. The tensile force to debond bleached teeth of Groups 2 and 3 tended to be lower than the control (Group 1) and are shown in Figure 3. However, the Kaplan-Meier test ($X^2=0.908$) did not indicate a significant difference between bleached and control samples ($P=0.635$).

Residual adhesive. To assess the amount of resin left on the enamel surfaces after debonding, the ARI scores[25]

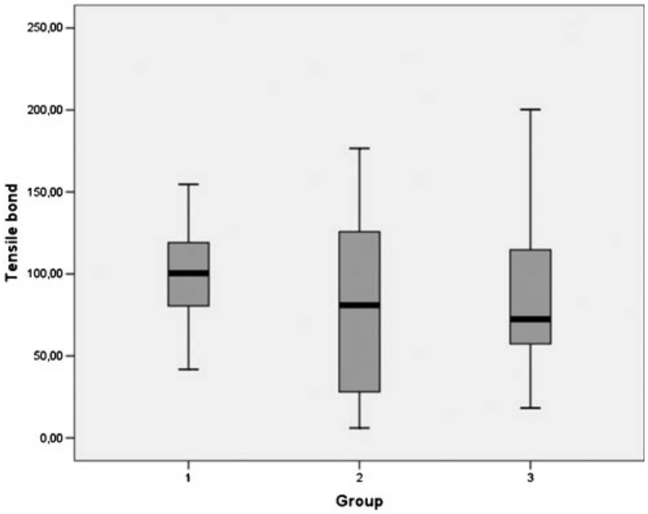


Figure 3 Tensile force debond (N) for each Group

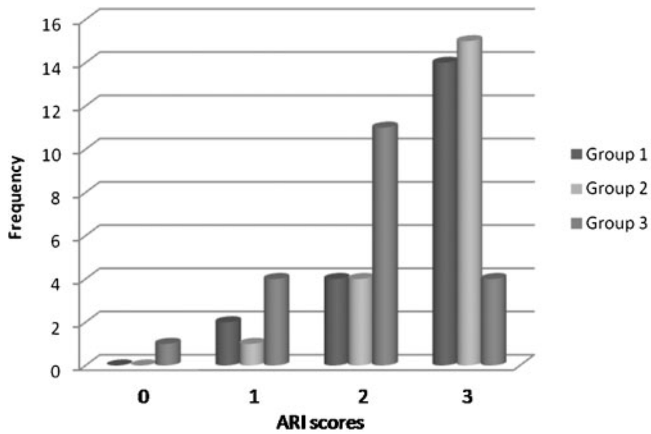


Figure 4 Frequency of adhesive remnant index (ARI) of Groups

were used (Figure 4). Examination of the tooth surfaces and bracket bases indicated that failures mainly occurred at the adhesive/bracket interface for Groups 1 and 2. In Group 3, failure occurred mainly within the adhesive.

Scanning electron microscopy (SEM). In Group 1, the fractured specimens from the tensile bond test had adhesive resin that was more uniform and free of pores, whereas in Groups 2 and 3, the adhesive resin appeared to be more granular and porous, especially in Group 3 (Figure 5).

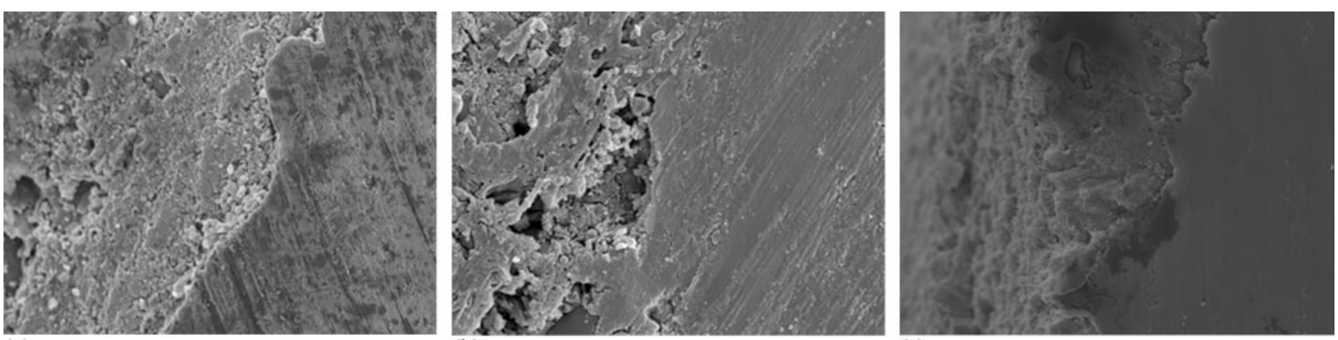
Evaluation of bleaching effect on enamel surface

Scanning electron microscopy (SEM). The test showed that scratches and pitting were common on the surface of all samples. In Group 1, the enamel surface was smoother than in the experimental groups. On the bleached surfaces, the density of pitting and scratches was increased, particularly for Group 3 (Figure 6).

Light microscopy. Examination of the hard tissue sections under a polarizing microscope revealed no changes in the samples of the three groups. In all sections, the normal histological features of the enamel were clearly evident, including the regular pattern of the crystalline structure within the enamel and the striae of Retzius (Figure 7).

Discussion

Various whitening systems and techniques are currently being used to bleach enamel.[1,9,10,21] Although clinically there is no consensus on the best bleaching method, in this experiment, we used 35% hydrogen peroxide activated with LEDs to speed up the whitening reactions and reduce the total experiment procedure.[26,27]



(a) (b) (c)

Figure 5 Scanning electron micrograph of resin/enamel interface (original magnification ×1700). (a) Control tooth showing adhesive resin more uniform and pore-free; (b) tooth of Group 2 with adhesive resin granular and porous and (c) tooth of Group 3 with adhesive resin more granular and porous

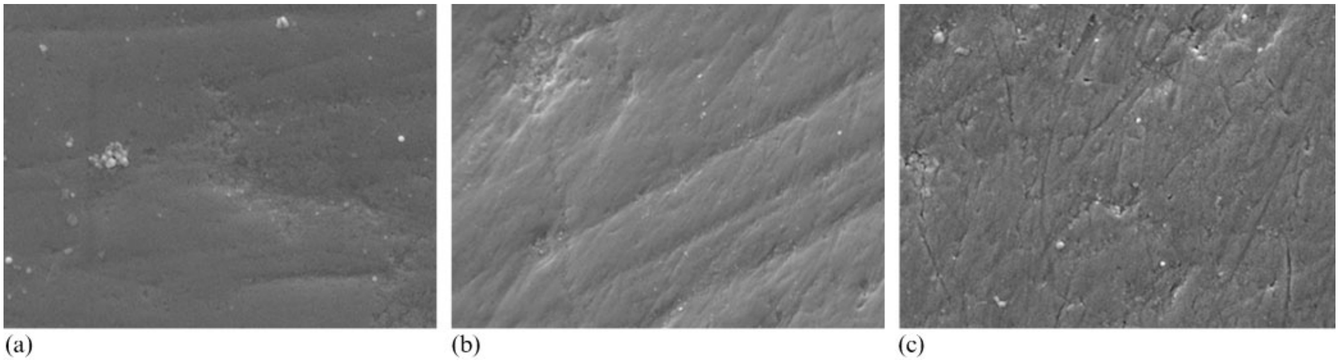


Figure 6 Photomicrographs (SEM) of enamel surface (original magnification ×5000). (a) Unbleached tooth; (b) bleached enamel with pitting and scratches and (c) double bleached tooth with density of pitting and scratches increased

In orthodontics, the bonding of attachments to tooth surfaces is temporary, in so far as the attachments are removed at the conclusion of the active treatment period.[28] In 1975, Reynolds stated that 6–8 MPa was the clinically acceptable force needed to retain bonded brackets.[16,29] These bond strengths are considered capable of withstanding masticatory and orthodontic forces.[16] In our results, the means of all Groups were within the minimum requirement for bonding (control group, 98.86 N (7.18 MPa); bleached teeth, 80.98 N (6.07 MPa) and 92.67 N (6.71 MPa).

This in vitro laboratory study attempted to simulate the conditions in the mouth including aging of the teeth, however to confirm these findings for clinical practice would require a properly carried out clinical trial.

Remineralization, diet, oral habits and abrasive tooth brushing may affect the long-term colour stability obtained with bleaching. Furthermore, bleached teeth can be expected to gradually return to their original discoloration over time, thus requiring retreatment.[1,20,22] In this study, aging with UV followed by a second whitening procedure was performed in order to simulate retreatment. Our goal was to investigate whether successive whitening procedures would significantly impact tensile force to debond and alter the enamel surface. Although the mean tensile forces to debond in bleached Groups 2 and 3 were lower than in the control group, statistical analysis found no significant differences among the three groups ($P=0.635$).

Several investigations using SEM suggest that tooth bleaching causes morphological alterations in the enamel surface[1,8,12,17,20,30,31] and that these structural changes could reduce bond strength; however, this finding is rather controversial.[16]

In this study, the SEM analyses detected alterations in the enamel surface of bleached groups, including an increased density of pitting and scratches. These alterations do not seem to significantly influence bond strength; however these data should be interpreted carefully because only two specimens from each group were examined with SEM. This study is in accordance with the other findings from Bishara *et al.*, who observed tooth enamel before and after a bleaching procedure and found that bleaching had a mild etching effect on the enamel surface, but did not observe a reduction in bond strength.[1]

It has also been proposed that bond strength is reduced by the presence of residual oxygen, which interferes with

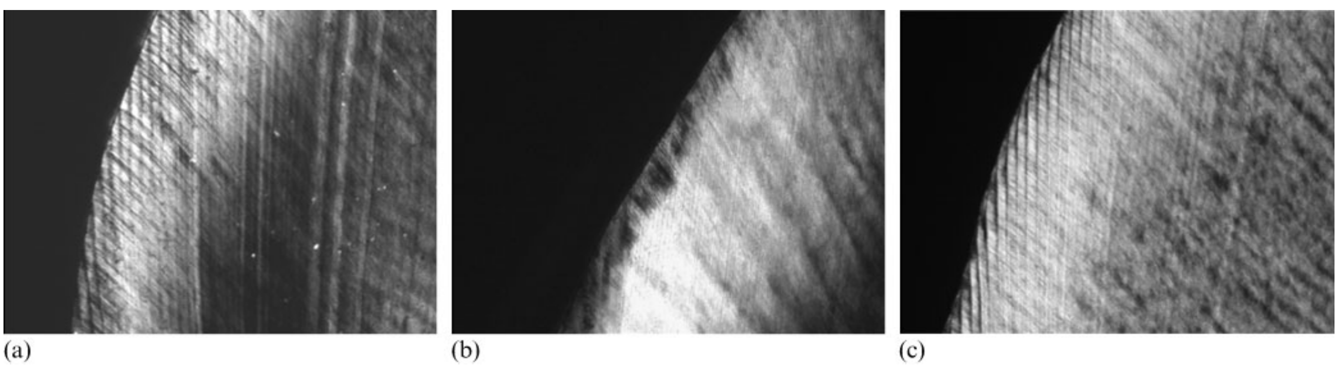


Figure 7 Polarizing light photomicrograph of enamel (original magnification ×10) showing the regular pattern of the crystalline structure and the striaes of Retzius. (a) Control Group; (b) Group 2 and (c) Group 3

resin infiltration into the etched enamel and/or inhibits the polymerization of resin.[2,32–34] In the present study, porosity in the resin/enamel interface of bleached teeth did not influence tensile force to debond. Bulut *et al.*[2] reported a bubbly appearance of the adhesive resin on bleached enamel surfaces that might have been caused by residual oxygen in the enamel structure.

Previous investigations have demonstrated that the immersion of *in vitro* specimens in artificial saliva, distilled water or even saline results in a complete reversal of the reduced enamel bond strength.[2,5,18,19,35] This may be due to removal of residual oxygen and contaminants from the bleaching material by the immersion process, which in turn results in more effective etching and resin penetration.[2,5,18,19] The idea that a delay following bleaching is required to return the bond strength to a pre-bleaching level is controversial. The porosity found in the resin/tooth interface in the experimental groups (Figure 4) shows that seven days may not be enough to eliminate residual oxygen and completely reverse the effects of the bleaching procedures. However, in this study, porous adhesive had little effect on tensile bond strength when compared to the control. Bulut *et al.*[19] observed that a period of seven days post bleaching was sufficient to obtain adequate tensile bond strength for clinical conditions. Cavalli *et al.*[9] affirmed that a period of up to three weeks is required before resin–enamel bond strengths return to values obtained for unbleached enamel. Turkun *et al.*[35] observed that the changes in enamel surface morphology seen immediately after bleaching returned to almost normal within three months. In this study, the specimens were immersed in artificial saliva for one week after bleaching, as suggested by Bulut,[2,19] to eliminate residual oxygen that could interfere with bonding.

It was also observed that changes in the enamel were superficial for the experimental groups. As seen on a polarizing microscope, the structures of bleached and unbleached enamel were similar, as exemplified by the blurring of the striae of Retzius and the darkening of the subsurface zone of the enamel as found by Josey *et al.*[20]

This *in vitro* study suggests that, in clinical practice, successive whitening procedures would not significantly impact tensile force to debond orthodontic brackets, although bleaching alters the enamel surface and the resin/enamel interface.

Conclusions

- The use of a 35% hydrogen peroxide in-office bleaching system seven days before bonding does not significantly reduce the tensile force to debond orthodontic brackets *in vitro*, even after a second bleaching procedure.
- In the majority of cases, debonding occurs at the adhesive/bracket interface or within the adhesive.
- Bleaching alters the enamel surface and the resin/enamel interface, but does not influence bond strength.

Contributors

Fernanda Danielle Mishima was responsible for the conception and design of this study; analysis and interpretation of data. Raquel Gomes de Almeida Valentim, Monica Tirre de Souza Araújo e Antonio Carlos de Oliveira Ruellas were reponsible for drafting and critical revision. Eduardo Franzotti Sant'Anna was responsible for the conception and design of this study; analysis and interpretation of data, and final approval of the article. Eduardo Franzotti Sant'Anna is the guarantor.

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