Original Research

Long-Term Color Stability of Orthodontic Adhesives after Exposure to Different Staining Agents

Abstract

Context: The aims of this study were (i) to evaluate the color stability of two orthodontic adhesives and (ii) to evaluate the color stability of enamel and ceramic brackets bonded with orthodontic adhesives after exposure to different staining agents. **Materials and Methods:** Disks were prepared with two orthodontic adhesives (Transbond and Enlight). Color stability evaluation was performed with a spectrophotometer using CIELab parameters. The specimens were divided into four groups and immersed in the following staining agents ($n = 5$): distilled water (control), coffee, red wine, and cola soft drink, for 1 h/day for 120 days. Twenty molar crowns were also used. The baseline color of enamel was obtained and ceramic brackets were bonded with the orthodontic adhesives. The enamel specimens were divided into four groups and immersed in the same staining agents. After 120 days, another color reading with the brackets in position was taken. The brackets were then removed and the enamel color was again evaluated. Color difference (ΔE) in different time periods was determined and the data were analyzed by ANOVA and Tukey's test ($\alpha = 5\%$). **Results:** Transbond showed lower ΔE than Enlight. Water, cola, and coffee had the lowest ΔE values. Immersion in wine showed the highest ΔE values. For time, the lower ΔE values were found for 24 h and 7 days. Storage times of 60, 90, and 120 days showed the highest ΔE values. ΔE for enamel showed significant differences only for time. **Conclusion:** Adhesive, staining agents, and storage time influenced the color stability of orthodontic adhesives.

Keywords: *Dental enamel, orthodontic adhesives, orthodontic brackets*

Thiago Vinícius Pavelski, Daniel Gheur Tocolini, Gisele Maria Correr, Leonardo Fernandes da Cunha, Carla Castiglia Gonzaga

School of Health Sciences, Graduate Program in Dentistry, Positivo University, Curitiba, Brazil

Introduction

The use of ceramic brackets has become more common as an alternative to metallic ones because a significant part of the adult population needs orthodontic treatment and expects better dental esthetics and natural appearance of the smile.

Esthetics can be considered the main advantage of ceramic brackets. However, one major disadvantage is their high bond strength values to enamel that, during debonding procedures, can cause bracket fracture and damages to the enamel surface.[1] It is important to note that despite ceramics are materials exhibiting excellent color stability, some *in vitro* studies have shown that ceramic brackets can present color alterations when exposed to coffee, black tea, and red wine, after a 21-day period of immersion in these media.[2]

In esthetic areas, orthodontic adhesives must not only maintain the fixation of brackets but also a satisfactory appearance throughout the treatment. Staining is especially problematic when orthodontic adhesives are subjected to prolonged exposure to drinks and foods with high pigmentation potential. Thus, color stability should be considered an important criterion for the selection of orthodontic adhesives for bonding esthetic brackets.[3]

Many studies have focused on the assessment of physical and mechanical properties of resin orthodontic adhesives and bond strength of brackets to enamel. However, color stability of orthodontic adhesives for bonding ceramic brackets was investigated only in a few studies.[3-5] Furthermore, there is evidence that bonding and removal of orthodontic brackets may cause changes in the appearance of dental enamel, including the presence of white spots[6] and color change after different procedures for bracket debonding and cleaning.[7-10]

After debonding of ceramic brackets, alterations on enamel roughness and color

Address for correspondence:
Dr. Carla Castiglia Gonzaga, Positivo University, Pedro Viriato Parigot de Souza 5300, Curitiba, Paraná 81280-330, Brazil.
E-mail: carlacgonzaga2@gmail.com

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may result from discoloration of the remaining orthodontic adhesives that impregnated the dental surface irreversibly, in spite of cleaning-up procedures. These resinous remains may alter tooth color because of physicochemical modifications in its structure and because of external factors, caused by superficial absorption of pigments from foods and drinks.[11]

The color stability of composite resins, category in which are included orthodontic adhesives, may be affected by several factors such as water sorption,[12] inadequate or incomplete polymerization,[13] photoinitiator system,[14] bad hygiene habits and biofilm accumulation,[15] and exposure to drinks and foods with high pigmentation potential, such as coffee, cola-based soft drinks, tea, and red wine.[16,17]

The objectives of this study are to (i) evaluate the color stability of two orthodontic adhesives used to bond ceramic brackets after exposure to different staining agents and (ii) evaluate the color stability of human enamel and ceramic brackets bonded with orthodontic adhesives after exposure to different staining agents. The hypotheses to be tested are as follows: (i) the commercial brand of orthodontic adhesive would influence the color stability of enamel and materials tested, (ii) the staining agents would influence the color stability of orthodontic adhesives and enamel, and (iii) storage time in different staining agents would influence the color stability of the orthodontic adhesives and enamel.

Materials and Methods

Color stability of orthodontic adhesives

Forty disk specimens 6 mm in diameter and 1 mm in height were prepared with two orthodontic adhesives (Transbond XT, 3M Unitek, Monrovia, CA, USA; and Enlight LV, Ormco, Orange, CA, USA) using a Teflon mold. The specimens were photoactivated with a LED-curing unit (Dental Woodpecker LED, China), with irradiance of 1200 mW/cm^2, according to manufacturers' instructions. The irradiance of the light source was previously measured by a radiometer (LED Demetron, Kerr, Middleton, WI, USA).

The color measurements were performed with a spectrophotometer (EasyShade Advance, Vita Zahnfabrik, Bad Säckingen, Germany) according to the CIELab (Commision Internationale de l'Eclairage, L^*, a^*, b^*) coordinates. Baseline color parameters were determined 10 min after photoactivation and over a white background. The specimens were randomly distributed in four groups and then stored in dark canisters containing the following staining agents (n = 5): distilled water (control), coffee [dissolution of one teaspoon of instant coffee (Nescafe) in 20 mL of water], red wine (Concha Y Toro), and cola-based soft drink (Coca Cola). The samples were kept in these solutions for 1 h/day during 120 days, at room temperature. The solutions were renewed every 3 days. During the remaining time, the specimens were stored in distilled water.

The CIELab coordinates were used to calculate the color difference (ΔE) between the "before" and "after" periods of 24 h, 7 days, 30 days, 60 days, 90 days, and 120 days. Color difference (ΔE) between baseline and subsequent readings was calculated according to the following equation:

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Where ΔL^*, Δa^*, and Δb^* are the differences between the parameters before (*baseline*) and after each period of time.

ΔE smaller than one were considered clinically imperceptible. When between 1 and 3.3, color change was considered acceptable. Values higher than 3.3 were considered clinically relevant and highly noticeable.[18]

Color stability of enamel and ceramic brackets bonded with orthodontic adhesives

Twenty human molars with intact crowns were used in this study after approval by the Institutional Review Board (Research Ethics Committee of Positivo University, CAAE number: 48569015.4.0000.0093, approval number: 1.226.713, approval date: September 14, 2015). The teeth were cleaned with periodontal curettes, polished with rubber cups and pumice, washed, and dried. The roots were cut and the pulp chamber access was sealed with composite resin (shade A3, NT Premium, Coltene, Rio de Janeiro, RJ, Brazil). All the surfaces, except vestibular and lingual where the brackets would be bonded, were sealed with two layers of nail polish to avoid excessive pigmentation from the solutions in the eventual presence of cracks and enamel defects.

Before bonding the ceramic brackets, the determination of enamel color parameters was performed with a spectrophotometer, in the exact areas where the brackets would be bonded. The ceramic brackets (Gemini Clear, 3M Unitek, Landsberg, Germany) were bonded on the vestibular and lingual surfaces with the two tested orthodontic adhesives, following the manufacturers' recommendation.

The enamel specimens (n = 5) were then randomly distributed in four groups and immersed in the same staining agents, as described in the previous session (1 h/day during 120 days).

After 120 days, the color parameters of the set enamel + orthodontic adhesive + ceramic bracket were evaluated with the tip of the spectrophotometer directly over the brackets while they were still bonded. The brackets were then removed with a bracket removal plier 346 (Schobell Industrial, Quinelato, Rio Claro, SP, Brazil) and the dental surface was cleaned with finishing and polishing tips (OneGloss, Shofu, Kyoto, Japan). The color parameters of the enamel surface in the area in which the brackets were bonded were determined again. Color difference (ΔE) between the first and the subsequent readings was then calculated using the equation described on the previous session.

Statistical analysis

The ΔE results were analyzed by three-way ANOVA (orthodontic adhesive, media, and time) with repeated measures and Tukey's honestly significant difference test ($\alpha = 0.05$).

Results

Color stability of orthodontic adhesives

The mean values of ΔE with standard deviations are presented in Table 1. Statistical analysis showed significant differences for all individual factors, double and the triple interactions ($P < 0.0001$).

Considering the individual factors, for orthodontic adhesive, Transbond XT (6.26) presented a lower ΔE when compared to Enlight LV (8.55). Regarding the storage media, water (5.70), Coca Cola (6.70), and coffee (6.76) presented the lowest ΔE values, which were statistically similar. Wine presented the highest ΔE value (10.46). As for time, the lower ΔE values were found for 24 h (4.14) and 7 days (4.40), which were statistically similar, followed by 30 days (6.55). The time periods of 60 days (9.97), 90 days (9.75), and 120 days (9.60) presented the higher ΔE values.

Observing the data in Table 1 and considering the critical ΔE value of 3.3, it is possible to verify that only four groups present ΔE values lower than this threshold: Transbond XT in water for the period of 24 h, 7 days, and 30 days; and Enlight LV in water for 24 h.

Color stability of enamel and ceramic brackets bonded with orthodontic adhesives

The ΔE results for enamel before bonding and after debonding of ceramic brackets are shown in Table 2. The statistical analysis showed significant differences only for time (initial and after 120 days of storage) ($P < 0.0001$). The factors adhesive and media, and all double and triple interactions, were not statistically significant ($P > 0.05$).

Considering the adhesives, Transbond XT (14.25) and Enlight LV (14.85) presented statistically similar ΔE values. For the storage media, wine (13.40), Coca Cola (14.47), coffee (14.90), and water (15.43) also presented statistically similar ΔE values. Regarding time, there was a statistical difference when comparing the ΔE values between enamel color after 120 days of storage and the initial color (6.90), in relation to the color of the set enamel + orthodontic adhesive + ceramic bracket after 120 days of storage and the initial color of the tooth (22.20).

Discussion

The first hypothesis of this study was accepted for the adhesives and rejected for the enamel. In the present work, considering the color stability of the orthodontic adhesives, Transbond XT presented lower ΔE when compared to Enlight LV.

Color alterations of polymeric materials may result from a great variety of factors, including exogenous discoloration from the superficial absorption of pigments from foods and drinks, mouth wash and bacterial biofilm, endogenous discolorations attributed to alterations on the chemical structure of the polymer, and internal discoloration (on the bulk of the material) due to the incomplete conversion of monomers and residual presence of photoinitiator.[4,19,20]

Color alterations in the present study can also be attributed to difference in the composition of materials. Although the two orthodontic adhesives used are based on methacrylate, they differ in chemical formulation, polymeric structure, and proportion of monomers, level of cross-linking, residual monomers, and amine concentration. These differences may lead to modifications in the polar nature of polymers, altering their susceptibility to absorb water and pigments, which may result in color change.[21,22] Besides, the type of filler particle and its quantity may affect the stability of composites,[14] since materials with higher levels of inorganic particles tend to present higher color stability than the composites with a lower amount of filler.[22]

In the present study, Transbond XT presented lower pigmentation potential than Enlight LV. Data from Table 1 show that Enlight LV presented ΔE values significantly

Table 1: Means and standard deviations for ΔE values according to orthodontic adhesives, staining agents, and time

Adhesive	Staining agent	Time					
		24 h	7 days	30 days	60 days	90 days	120 days
Transbond XT	Water	$1.64\pm0.66^{a,b}$	$1.70\pm0.35^{a,b}$	1.37 ± 0.31^{a}	$4.23\pm1.16^{a\text{-}e}$	$4.32\pm1.10^{a\text{-}f}$	$4.15\pm0.91^{a,b,c,d,e}$
	Coca Cola	$5.97\pm0.77^{a\text{-}h}$	$4.26\pm0.59^{a\text{-}f}$	$5.74\pm0.98^{a\text{-}h}$	$6.23\pm1.24^{b\text{-}h}$	$6.89\pm1.52^{c\text{-}j}$	$5.55\pm1.33^{a,b,c,d,e,f,g}$
	Coffee	$3.45\pm1.77^{a\text{-}d}$	$4.14\pm2.04^{a\text{-}e}$	$4.94\pm2.10^{a\text{-}f}$	$6.16\pm0.46^{b\text{-}h}$	$7.11\pm0.66^{c\text{-}j}$	$7.08\pm0.61^{c\text{-}j}$
	Wine	$5.83\pm0.42^{a\text{-}h}$	$7.10\pm1.29^{c\text{-}j}$	$11.07\pm1.40^{j\text{-}q}$	$12.56\pm1.38^{l\text{-}q}$	$14.33\pm1.85^{p,q}$	14.48 ± 1.60^{q}
Enlight LV	Water	$3.69\pm0.86^{a\text{-}d}$	$2.63\pm1.17^{a\text{-}c}$	$8.63\pm3.39^{e\text{-}n}$	$12.58\pm13.25^{m\text{-}q}$	$13.86\pm5.24^{p,q}$	$9.63\pm3.18^{g\text{-}o}$
	Coca Cola	$4.12\pm0.95^{a\text{-}e}$	$3.39\pm1.77^{a\text{-}d}$	$3.80\pm0.99^{a\text{-}d}$	$12.68\pm2.11^{n\text{-}q}$	$9.83\pm1.15^{g\text{-}p}$	$11.91\pm0.99^{k\text{-}q}$
	Coffee	$4.61\pm1.11^{a\text{-}f}$	$6.53\pm1.21^{c\text{-}j}$	$7.99\pm0.66^{d\text{-}m}$	$11.02\pm2.09^{i\text{-}q}$	$7.91\pm2.04^{d\text{-}k}$	$10.20\pm1.35^{h\text{-}q}$
	Wine	$3.81\pm0.68^{a\text{-}d}$	$5.49\pm0.79^{a\text{-}g}$	$8.88\pm1.12^{f\text{-}n}$	$14.34\pm1.15^{p,q}$	$13.79\pm1.16^{o\text{-}q}$	$13.79\pm1.72^{o\text{-}q}$

Values followed by the same superscripts are statistically similar ($P>0.05$)

Table 2: Means and standard deviations of Δ*E* values for enamel and set of enamel + adhesive + bracket after 120 days of storage in different staining agents

Adhesive	Staining agent	ΔE (final enamel/initial enamel)	Δ*E* set (enamel + adhesive + bracket/ initial enamel)
Transbond XT	Water	6.41±2.44[a]	25.35±4.32[c]
	Coca Cola	6.45±2.69[a]	21.00±1.83[c]
	Coffee	7.39±1.54[a]	21.47±8.59[c]
	Wine	6.70±4.48[a]	19.27±2.07[b,c]
Enlight LV	Water	5.97±0.76[a]	23.99±7.33[c]
	Coca Cola	6.94±2,43[a]	23.49±2.85[c]
	Coffee	8.93±4.13[a,b]	21.81±2.39[c]
	Wine	6.41±2.95[a]	21.23±4.47[c]

Values followed by the same superscripts are statistically similar (*P*>0.05)

higher than Transbond XT, when stored in water, Coca Cola, and coffee. Only for storage in wine, Δ*E* values were the highest and similar for both orthodontic adhesives. Other studies reported similar results. Eliades *et al.*[4] evaluated the color stability of orthodontic adhesives subjected to artificial photoaging. The results showed that Transbond XT presented Δ*E* values of 3.26, whereas Enlight LV presented significantly higher (and clinically relevant) values (8.36).

The second and the third hypothesis are related, since they deal with the influence of staining agents and immersion time on the color stability of orthodontic adhesives. The second hypothesis was accepted for the adhesives and rejected for enamel. In the present study, considering color stability of adhesives, wine presented the highest values of Δ*E*, followed by water, Coca Cola, and coffee, which were statistically similar. The third hypothesis was accepted for both adhesives and enamel.

As previously suggested, the color of polymeric materials can be affected by its immersion in water during long periods of time, due to the hydrophilic behavior of the polymeric matrix and consequent absorption of water by the material.[21,22]

Cola-based soft drinks, coffee, and wine are beverages commonly consumed and previous studies have demonstrated color alteration of composite materials after exposure to these solutions.[17,23,24] In the present study, immersion in water, Coca Cola and coffee presented similar results. However, it must be noted that only Transbond XT, stored in water for 24 h, 7 days, and 30 days and Enlight LV stored in water for 7 days, presented Δ*E* values lower than 3.3. The exposure during any amount of time in the other staining solutions produced Δ*E* values higher than the critical threshold. This result may be partially explained by the fact that, in previous studies, cola-based drinks do not seem strongly implicated in the color alteration of composite materials, in spite of the presence of phosphoric acid in the composition.[25,26] Studies report that wine is one of the solutions with highest potential of staining composite resin.[17,23] One of the explanations may be the presence of alcohol in wine, which may have contributed even more for the superficial degradation of the materials and their discoloration.

In the present study, Δ*E* values showed a tendency of increase as the period of immersion became higher, regardless the staining agent, suggesting that the color of the composite would tend to change with long-term clinical use. This study evaluated the color alteration of orthodontic adhesives for 120 days, with 1 h of immersion in the staining agents per day. Although this period may not be considered as long term, the results indicated that after 60 days of storage, there was no statistically significant difference in the Δ*E* values for most of the groups evaluated. These data suggest that the materials evaluated presented an increase in Δ*E* values until 60 days of immersion and, from then on, stabilized. This is due to the fact that the composites present higher levels of pigmentation at the early stages of exposure to the oral environment, especially on the first week.[10]

The first part of this study evaluated the color stability of orthodontic adhesives after immersion in different staining agents. The second part evaluated the color stability of enamel and orthodontic adhesives after bonding and debonding of ceramic brackets, and the immersion in the different solutions. The results showed statistically significant differences for Δ*E* of enamel (final enamel after 120 days of storage/initial enamel) (6.90) and Δ*E* of set (enamel + adhesive + bracket after 120 days of storage/initial enamel) (22.20). These data indicate that, after the immersion in the staining agents, they suffered color alterations, although the effect was much more visible and significant when the orthodontic adhesive and the ceramic bracket were still bonded. However, there was no influence of the adhesive or solution in this situation.

After orthodontic therapy, an iatrogenic color change of enamel must be expected by both orthodontist and patient. Thus, all the adhesive remnants must be carefully removed and, if a clinically relevant enamel discoloration persists, dental bleaching could be recommended.

Some orthodontic adhesives may have less effect on the discoloration of enamel than others, depending on the adhesive remnants, enamel penetration, and ease of removal. Even though the adhesives tested are both composite resins, there was a significant difference between the commercial brands. Therefore, orthodontists must pay attention to the potential of color alteration of the orthodontic adhesives when choosing the material to bond ceramic brackets. Orthodontists must also instruct their patients that much of the color alteration of the orthodontic adhesives would occur in the first 60 days and that some commonly consumed foods and beverages are potentially more critical than others in relation to the color stability of the adhesive.

Conclusion

It can be concluded that the adhesive, staining agent, and storage time influenced the color stability of the two orthodontic adhesives tested. Transbond XT presented higher color stability than Enlight LV. Wine presented the highest Δ*E* values for all adhesives. Regarding storage time, after 60 days, the highest Δ*E* values were observed and remained similar for up to 120 days. There was no influence of the orthodontic adhesive and staining agent on the color change of the enamel specimens. However, the enamel showed significant color difference after 120 days in relation to its initial value, in all groups evaluated.

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Conflicts of interest

There are no conflicts of interest.

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