Color stability of five orthodontic clear elastic ligatures

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\textbf{Aim:} In this study the color stability of five commercially available orthodontic clear elastic ligatures daily exposed to a staining agent (red wine) was investigated. \textbf{Methods:} The commercial brands tested were 3M Unitek, Abzil, American Orthodontics, Dentsply GAC, and Morelli. Baseline color readings (Commission Internationale de l’Eclairage [CIE] L*a*b* parameters) of 20 ligatures for each brand were carried out using a spectrophotometer. The ligatures were divided in two groups (n = 10): one group remained immersed in distilled water (control) throughout the period, while the other group was daily exposed to red wine (1 hour of immersion). Immersion media were daily renewed. Successive color readings were carried out after 7, 14, 21, and 28 days, and the chromatic variations calculated. Color variation data were analyzed by two-way repeated measures analysis of variance and Student-Newman-Keuls test (\(P < .05\)). \textbf{Results:} Storage in water increased staining until 14 days, and color receded after this period, irrespective of the brand. After 28 days of immersion in water, no significant difference among the commercial brands was observed. For the groups exposed to red wine, a significant increase in staining over the course of time was detected, irrespective of the brand. Ligatures from GAC and Morelli showed higher staining than the other materials, irrespective of the evaluation time. Ligatures from 3M Unitek and American generally showed lower pigmentation than the other brands. \textbf{Conclusion:} Exposure to a staining agent, cumulative exposure time, and commercial brand are factors that influence the color stability of clear elastic ligatures. \textit{Orthodontics (CHIC)} 2013;14:e60–e65. doi: 10.11607/ortho.892

\textbf{Key words:} CIE L*a*b*, clear ligatures, spectrophotometer, staining, translucency

In clinical orthodontics, metallic (dead soft) or colored (elastic) ligature ties are frequently used with stainless steel brackets to hold the archwire in place. However, clear (translucent) elastic ligatures are commonly used with ceramic brackets to aid in providing esthetic appearance to the appliances. In addition to alteration in the physical properties of elastic ligatures during intraoral service,\textsuperscript{1,2} clear ligatures may present color variation as a function of the contact with some dietary media.\textsuperscript{3} This may result in a significant problem because, as the ligature stains, the bracket-ligature system becomes...
less esthetic. In such a situation, the esthetic issue may become the main determinant of the interval between clinical appointments rather than the appliance activation itself. Therefore, the clinician might spend considerable clinical time changing stained ligatures, which may also increase the cost of the treatment.

Previous studies have investigated the color stability of orthodontic adhesives and brackets exposed to pigments, food-simulating media, or beverages. In contrast, little is known regarding the color stability of orthodontic elastic ligatures. Kim and Lee investigated the color variation of clear ligatures using a digital camera; the materials were exposed to a methylene blue solution, which might be considered a severe condition. Ardeshna and Vaidyanathan exposed the ligatures to four dietary media using continuous immersion for 72 hours. In the oral environment, however, the periods of exposure to staining agents are shorter.

The staining of clear modules might be dependent on the material tested as well as the staining agent and duration of exposure. The aim of this study was, therefore, to investigate the color stability of five orthodontic clear ligatures, daily exposed to a staining agent, during a total period of 28 days of exposure. The hypothesis tested was that the color stability would be dependent on the time the ligatures were exposed to the staining agent.

**METHODS**

**Study design and materials tested**

This in vitro study involved a $2 \times 5 \times 4$ factorial design ($n = 10$). The factors under evaluation were: storage condition (two levels: exposure or not to the staining agent), material (five levels: different elastic ligatures), and storage time (four levels: 7, 14, 21, and 28 days). Five commercially available latex-free elastomeric clear ligatures were tested: 3M Unitek, Abzil, American Orthodontics, Dentsply GAC, and Morelli. The same specimen (each elastic ligature) for each storage condition was analyzed in all storage times (repeated measures approach). The response variable was color variation ($\Delta E$).

**Storage conditions and color readings**

Ligatures were stretched before color measurements. Baseline color readings for each specimen were carried out using a spectrophotometer (model SP60; X-Rite) based on the Commission Internationale de l’Eclairage (CIE) L*a*b* system, similar to what has been previously described by Fontes et al. The readings were performed using a white background, and the values for parameters L*, a*, and b* for each specimen were recorded. Thereafter, the specimens were stored in distilled water ($\text{pH} = 6.6$) at $37^\circ$C for 28 days. During this period, half the number of specimens of each brand ($n = 10$) was daily exposed to red wine (San Martín) as staining agent, with 10.4% v/v alcohol ($\text{pH} = 3.3$). Red wine was chosen for its staining potential showed in pilot studies with different diet agents. The specimens were immersed in the red wine for 1 hour at $37^\circ$C, washed in running tap water, and stored again in distilled water at $37^\circ$C until the next day.

The remaining specimens of each brand remained stored in distilled water at $37^\circ$C (control groups). For both groups (exposed or not to the staining agent), the immersion media (red wine and distilled water) were daily renewed. Color readings were repeated after 7, 14, 21, and 28 days. A 28-day exposure period represents an average time between orthodontic clinical appointments. For each evaluation time, the color variation ($\Delta E$) was calculated as previously described based on the baseline color individually measured for each specimen.
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Statistical analysis
Color variation data were submitted to two-way repeated measures analysis of variance (material × storage time) separately for the groups exposed or not to the staining agent. All pairwise multiple comparison procedures were carried out using the Student-Newman-Keuls method (P < .05).

RESULTS

Color variation for control groups (distilled water)
Results of color variation for the groups not exposed to the staining agent are shown in Table 1. The factor of material was not significant (P = .053), while the factor of storage time and the interaction between the factors were both significant (P < .001). In general, for all materials, there was a significant increase in staining until 14 days and, after that, the color receded significantly. Comparing the different materials, the ligatures from 3M Unitek generally showed significantly higher staining than ligatures from Abzil and Morelli until 21 days of storage, whereas the other materials showed intermediate results. After 28 days, no significant differences were observed among the different materials. Visual comparisons of new ligatures and ligatures stored in distilled water or daily exposed to red wine are shown in Fig 1. Color variation is not visually perceptible when comparing ligatures immersed only in distilled water and unused ligatures.

Color variation for groups exposed to the staining agent (red wine)
Results of color variation for the groups daily exposed to red wine are presented in Table 2. The factors of material and storage time were both significant, as was their interaction (P < .001). For all materials, a significant increase in staining at each evaluation time was observed compared with the previous time. Great variability of results was detected when comparing the different materials. In general, ligatures from GAC and Morelli showed higher staining than the other materials, irrespective of the evaluation time. Ligatures from 3M Unitek and American showed, generally, lower staining than the other brands, whereas intermediate results were observed for ligatures from Abzil. As shown in Fig 1, visually perceptible color variations were detected for all and only ligatures exposed to the staining agent, irrespective of the commercial brand.

Table 1  Means (standard deviations) of color variation (ΔE) for the control groups (n = 10)

<table>
<thead>
<tr>
<th>Material</th>
<th>Storage time</th>
<th>7 days</th>
<th>14 days</th>
<th>21 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3M Unitek</td>
<td>0.97 (0.3)B,a</td>
<td>1.14 (0.3)A,a</td>
<td>0.38 (0.4)C,a</td>
<td>0.39 (0.4)C,a</td>
</tr>
<tr>
<td></td>
<td>Abzil</td>
<td>0.70 (0.1)B,b</td>
<td>0.87 (0.1)A,b</td>
<td>0.10 (0.1)D,b</td>
<td>0.24 (0.1)C,a</td>
</tr>
<tr>
<td></td>
<td>American</td>
<td>0.88 (0.1)A,ab</td>
<td>0.89 (0.2)A,ab</td>
<td>0.21 (0.2)B,ab</td>
<td>0.20 (0.2)B,a</td>
</tr>
<tr>
<td></td>
<td>GAC</td>
<td>0.73 (0.1)B,ab</td>
<td>0.87 (0.1)A,b</td>
<td>0.25 (0.1)C,ab</td>
<td>0.25 (0.1)C,a</td>
</tr>
<tr>
<td></td>
<td>Morelli</td>
<td>0.68 (0.1)B,b</td>
<td>0.79 (0.1)A,b</td>
<td>0.26 (0.3)C,ab</td>
<td>0.34 (0.1)C,a</td>
</tr>
</tbody>
</table>

Distinct uppercase letters in the same row indicate significant differences for storage time; distinct lowercase letters in the same column indicate significant differences for material (P < .05).
DISCUSSION

The results of the control groups indicate differences that may be significant among materials due to the accuracy of the equipment used for color readings but probably would have no major clinical impact. There is no consensus in the literature regarding chromatic variation limits measured by colorimetric tools and those limits that would be perceptible to the human eye. Most of the studies in the literature consider $\Delta E$ values higher than 3.3 as visually perceptible based on previous investigations.\textsuperscript{11–13} In this study, the $\Delta E$ values for the groups immersed in water were all $\leq 1.14$, irrespective of the commercial brand or storage time. In addition, as shown in Fig 1, no appreciable color changes were visually perceptible due to water storage. These findings indicate that the water was a good control medium as well as a good storage medium between the daily exposures to red wine. The color slightly receded with time when the ligatures were immersed only in water, which could simulate the effect that saliva may have in the oral environment.

### Table 2  Means (standard deviations) of color variation ($\Delta E$) for groups daily exposed to red wine ($n = 10$)

<table>
<thead>
<tr>
<th>Material</th>
<th>7 days</th>
<th>14 days</th>
<th>21 days</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M Unitek</td>
<td>1.79 (0.1)$^{D,cd}$</td>
<td>2.25 (0.1)$^{C,cd}$</td>
<td>2.92 (0.1)$^{B,c}$</td>
<td>3.17 (0.2)$^{A,d}$</td>
</tr>
<tr>
<td>Abzil</td>
<td>1.91 (0.1)$^{D,c}$</td>
<td>2.33 (0.3)$^{C,c}$</td>
<td>3.44 (0.1)$^{B,b}$</td>
<td>3.77 (0.1)$^{A,c}$</td>
</tr>
<tr>
<td>American</td>
<td>1.72 (0.1)$^{D,d}$</td>
<td>2.12 (0.2)$^{C,d}$</td>
<td>3.01 (0.1)$^{B,c}$</td>
<td>3.23 (0.2)$^{A,d}$</td>
</tr>
<tr>
<td>GAC</td>
<td>2.52 (0.1)$^{D,a}$</td>
<td>3.02 (0.2)$^{C,a}$</td>
<td>3.88 (0.1)$^{B,a}$</td>
<td>4.10 (0.1)$^{A,b}$</td>
</tr>
<tr>
<td>Morelli</td>
<td>2.16 (0.1)$^{D,b}$</td>
<td>2.72 (0.3)$^{C,b}$</td>
<td>3.84 (0.2)$^{B,a}$</td>
<td>4.31 (0.3)$^{A,a}$</td>
</tr>
</tbody>
</table>

Distinct uppercase letters in the same row indicate significant differences for storage time; distinct lowercase letters in the same column indicate significant differences for material ($P < .05$).
For all groups exposed to red wine, a significant increase in staining was observed for each evaluation time compared with the previous time. Therefore, the hypothesis tested is accepted. This finding indicates that the color stability of clear elastic ligatures is dependent on the cumulative period that the materials are exposed to the staining agent. This result also suggests the color variation observed for the elastic ligatures during the 28-day period from the daily exposure to red wine did not saturate. The color variations reported occurred by absorption of dark pigments from the red wine, impregnating the elastomeric material. Additional surface effects caused by the ethanol in the red wine and the low-pH of the staining agent might have contributed to the staining outcome.

Although all ligatures were subjected to the same storage protocols, great variability in color stability was observed among the different materials exposed to red wine. This indicates that the staining of clear elastic ligatures depends not only on the exposure to a pigment but also on the material. Considering a ΔE value of 3.3 as a limit of color variation that would be visually undetectable, only ligatures from 3M Unitek and American showed chromatic variations below this threshold during the 28-day period. However, as shown in Fig 1, all ligatures show distinguishable chromatic variations compared with the respective control and new specimens. This means that the ΔE value of 3.3, although suitable for restorative composites, cannot be considered a limit for the visibility of color variations when evaluating clear orthodontic elastic ligatures.

Although it is difficult to evaluate whether the specific composition of the ligatures may vary significantly among commercial brands, it is possible to observe that some ligatures are lighter (more translucent) than others (see Fig 1). Characteristics of the production process might affect the porosity, surface smoothness, and finish quality of the materials, which may also interfere with the absorption of pigments. Some ligatures are available individually, while others are available as ligature chains to be cut individually; the separation process might leave imperfections in the periphery of the materials, which may also affect the staining result. Imperfections are visible for some materials shown in Fig 1. Ardeshna and Vaidyanathan (2009) reported that ligatures made using injection moldings were more resistant to color change than those made by extrusion.

The findings of the present study provide evidence that the color stability of clear elastic ligatures may vary among different commercial brands. However, the in vitro conditions of the present study did not take into account the possible effects that dentifrice and brushing may have on the color stability of orthodontic ligatures. The effects of saliva were, to some extent, simulated by immersion in water after the daily exposure to red wine, as the ligatures tended to lighten due to water soaking. In addition, the present study was focused on comparing the elastic ligatures, not different staining agents; further studies investigating the color stability of clear elastic ligatures would aid the clinicians in choosing materials with longer-lasting color stability.

**CONCLUSION**

Despite the great time-dependent variability in results among the different commercial brands, it can be concluded that the color stability of orthodontic clear elastic ligatures is dependent on the exposure to a staining agent, cumulative exposure time, and material.
ACKNOWLEDGMENTS

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REFERENCES