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RESEARCH ARTICLE

Analysis of the Influence of Food Colorings in Esthetic Orthodontic Elastomeric Ligatures

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Abstract:

Proposition:

The purpose of this study was to evaluate *in vitro* the color changes of esthetic orthodontic elastomeric ligatures of different shades when exposed to four food colorings commonly found in the diet of patients.

Materials and Methods:

The sample consisted of esthetic orthodontic elastomeric ligatures in the colors pearl, pearl blue, pearl white and colorless, which were immersed for 72 hours in five different solutions: distilled water (control group), coffee, tea, Coca-Cola[®] and wine. The color changes of the esthetic orthodontic elastomeric ligatures were measured with the aid of a spectrophotometer, at T1 - as provided by the manufacturer; and T2 - after colorings process.

Results:

The results indicated that the esthetic orthodontic elastomeric ligatures of all initial hues are susceptible to pigmentation. Among the evaluated colors, all changed the finished look and the color of the samples tested. In ascending order, the color of the samples was as follows: distilled water, Coca-Cola[®], black tea, wine and coffee.

Conclusion:

The substances that have a greater potential for pigmentation in esthetic orthodontic elastomeric ligatures were black tea, wine and coffee, respectively. All shades of esthetic orthodontic elastomeric ligatures are susceptible to color change.

Keywords: CIE - Commission Internationale de l'Eclairage, Esthetic degradation, Esthetic orthodontic elastomeric ligatures, Food colorings, IRR (Incidence Rate Ratio), Pigmentation.

INTRODUCTION

The demand for esthetic orthodontic appliances has increased particularly in the treatment of adult patients has increased significantly in the orthodontic market [1, 2]. While the ceramic brackets are resistant to color change, orthodontic elastomeric are subject to staining by foods which have a high potential for colorings, resulting in a esthetic problem [3 - 8].

The ability to avoid colorings of esthetic orthodontic elastomeric ligatures has become a major challenge due to the

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fact that the oral environment is exposed to a variety of food colorings on a daily basis. Many of these colorings may stain, alter the surface of the elastomeric, and cause esthetic degradation. Therefore, it is important to know not only if the exposure to food colorings can change the color of the esthetic orthodontic elastomeric ligatures, but also if it is a change that can be perceived by the human eye [9].

In the orthodontic literature, little is found about it, probably due to limitations in measuring the colors of objects until a few years ago. Nowadays, studies often use colorimeters, spectrophotometers, or digital cameras to evaluate color changes. In preliminary studies, all esthetic orthodontic elastomeric ligatures tested presented color degradation larger than the threshold of human visual perception [1, 3, 9, 10].

To characterize the color changes of esthetic orthodontic elastomeric ligatures under the influence of food and drinks, the objective of this study was to evaluate *in vitro* the possible color change of esthetic orthodontic elastomeric ligatures of four shades exposed to different food colorings.

MATERIALS AND METHODS

This study was approved by the Ethics in Research Committee of the School of Dentistry at the Pontifical Catholic University of Rio Grande do Sul (FO-PUCRS) in Porto Alegre, Brazil. The main purpose was to evaluate the color of esthetic elastomeric orthodontic ligatures under the influence of the ordinary beverages present in the daily life. For this reason were employed similar esthetic colors from two different companies. The samples were divided into four groups of esthetic orthodontic elastomeric ligatures of different colors: colorless, pearl, pearl blue and pearl white (Table 1). Each orthodontic elastomeric ligatures was analyzed before and after a 72-hour immersion in one of the five solutions used. The total number of samples tested was 480 (4 different colors X 24 specimens X 5 solutions).

Table 1. Esthetic orthodontic elastomeric ligatures analyzed in the study.

Group	n	Color	Manufacturer
1	24	Colorless	American Orthodontics (Sheboygan, WI, USA)
2	24	Pearl	Ortho Technology (Tampa, FL, USA)
3	24	Pearl Blue	Ortho Technology (Tampa, FL, USA)
4	24	Pearl White	American Orthodontics (Sheboygan, WI, USA)

The following coloring solutions were used: Coca-Cola®, coffee (Três Corações, MG, BR); red wine (Viu Manet, cabernet sauvignon, reserve 2009, Chile) and black tea (Twinings of London, UK). Distilled water was used as control group. The black tea and coffee solutions were previously prepared according to the manufacturer's recommendations.

All the esthetic orthodontic elastomeric ligatures were separated into individual containers (Fig. 1) and immersed in the solutions for 72 hours at 37°C, according to the methodology proposed by Ardesna and Vaidyanathan [9] (2009). After the immersion process, the samples were cleaned with distilled water and dried with paper towel.

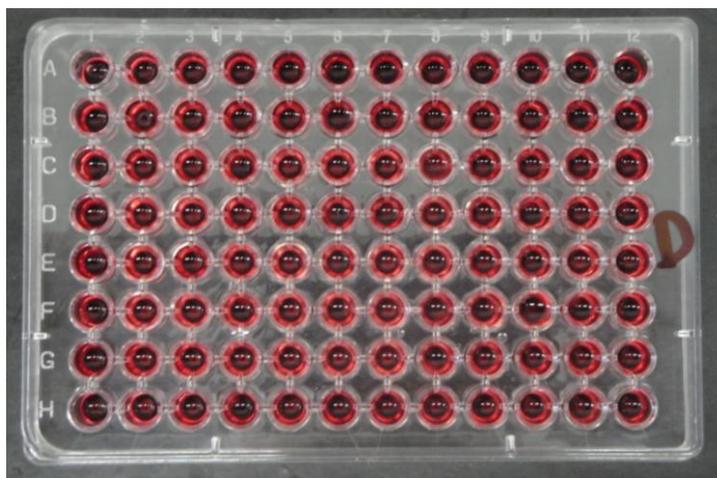


Fig. (1). Samples individualized and immersed in the red wine solution.

With the aid of a portable spectrophotometer SP60 (X-Rite, Grand Rapid, MI, USA) and on a white surface, each

sample was evaluated as provided by the manufacturer (T1) and after the immersion in the solutions (T2).

To calculate the intensity of the color variation numerically and quantitatively, the CIEL * a * b * color space was defined by the International Commission on Illumination (CIE - Commission Internationale de l'Eclairage) [11] in 1978. The CIEL * a * b * color space is made up of three coordinates L *, a *, b *. The coordinate L * refers to lightness and its values go from zero (completely black) to 100 (pure white). The coordinate a * indicates the chromaticity of the red to green axis, positive values indicate the red color and negative values indicate the green color. The b * coordinate indicates the chromaticity of the yellow to blue axis, positive values indicate the yellow color and negative values indicate the blue color [12].

The total alteration of color (ΔE) was calculated using the formula:

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

where $\Delta L^* = L^*_f - L^*_i$; $\Delta a^* = a^*_f - a^*_i$; e $\Delta b^* = b^*_f - b^*_i$, and the letters "i" e "f" represent the initial and final values.

The advantage of the CIEL * a * b * system is that the color differences can be expressed in units, allowing the relation with visual perception and clinical significance [13]. ΔE values greater than 3.3 are clinically visible, and this value was used to define the clinical significance [6].

All samples were analyzed by a single examiner blinded with random placements in the equipment, in order to obtain the individual average of each.

STATISTICAL ANALYSIS

Data were analyzed statistically using the STATA software 12.0 software (Stata Corporation, College Station, TX, USA). Testing for normality was carried out using the Kolgomorov-Smirnov test and revealed non-normal distribution. Data analysis was performed using generalized linear models by applying Poisson regression to determine the ratios of the averages of the esthetic orthodontic elastomeric ligatures group and the solutions groups, with group 1 and water solution as controls to compare with. The significance level used for all tests was 0.05.

RESULTS

The values found are presented descriptively in Table 2. By evaluating the results, it can be observed that the behavior of the groups was similar, as it can be verified in Table 3, where the change ΔE was not influenced by the color of the esthetic orthodontic elastomeric ligatures.

The IRR (Incidence Rate Ratio) is the average ratio, having as denominator the group with lower value. Thus, it is considered that group 2 has shown color change 1.08 times higher than group 1. It was not possible to determine statistically significant differences between the groups (Table 3).

When analyzing the figures for the solutions, it can be observed that they represent statistically significant influence on ΔE , as shown in Table 4. Coca-Cola® had the lowest variation, showing a variation 2 times higher than the control group. Coffee was the solution with the highest variation, presenting a variation 9.83 times higher than the control group.

The values helped confirm that regardless of the esthetic orthodontic elastomeric ligatures, the solutions exert statistically significant influence on ΔE .

Table 2. Descriptive statistics of the values found by the present study.

Descriptivestatistics				
Solution	group	N	Mean	Std. Deviation
Coca-Cola	1	24	1.21	0.35
Coffee	1	24	5.14	2.88
Tea	1	24	4.90	0.35
Wine	1	24	3.42	0.26
Water	1	24	0.35	0.08
Coca-Cola	2	24	1.05	0.17

(Table 2) contd.....

Descriptivestatistics				
Coffee	2	24	5.24	0.19
Tea	2	24	5.49	0.42
Wine	2	24	3.66	0.11
Water	2	24	0.76	0.11
Coca-Cola	3	24	0.93	0.14
Coffee	3	24	4.98	0.15
Tea	3	24	4.54	1.09
Wine	3	24	4.26	0.37
Water	3	24	0.57	0.11
Coca-Cola	4	24	1.04	0.09
Coffee	4	24	5.37	0.70
Tea	4	24	4.98	1.50
Wine	4	24	4.34	0.13
Water	4	24	0.44	0.10

Table 3. Distribution of groups tested by IRR (Incidence Rate Ratio).

Groups	IRR	Std. Err.	P	95% conf. interval	
2	1.08	0.08	0.293	0.94	1.25
3	1.02	0.08	0.812	0.88	1.18
4	1.08	0.08	0.309	0.93	1.24

Table 4. Distributions of the solutions tested by IRR (Incidence Rate Ratio).

Solutions	IRR	Std. Err.	P	95% conf. interval	
Coca-Cola®	2.00	0.35	0.00	1.43	2.80
Coffee	9.83	1.45	0.00	7.36	13.12
Tea	9.44	1.39	0.00	7.06	12.60
Wine	7.3	1.11	0.00	5.54	9.97

DISCUSSION

The choice of esthetic braces will be incomplete if the characteristics of the esthetic orthodontic elastomeric ligatures used for the application of orthodontic mechanics to the tooth are not analyzed. Esthetic orthodontic elastomeric ligatures can be colorless or in pearl color variations. Color change is observed after exposure to colorings present in food and drinks, regardless of the esthetic orthodontic elastomeric ligatures’s initial, and this is one of the known clinical shortcomings of elastomers. In order to identify the color change of esthetic orthodontic elastomeric ligatures under the influence of the most commonly ingested drinks by patients, this study has evaluated the color change of esthetic orthodontic elastomeric ligatures of different shades exposed to four different food colorings.

All solutions have changed the final aspect and color of the samples tested, regardless of the color of the esthetic orthodontic elastomeric ligatures. In ascending order, the color of the samples was as follows: distilled water, Coca-Cola®, black tea, wine and coffee.

These results are relevant due to the fact that adult patients are extremely critical of the esthetic orthodontic elastomeric ligatures and are frequent consumers of red wine, coffee and tea. In the study by Fernandes *et al.* [1], where the same solutions were tested, the results were equivalent, despite the fact that esthetic orthodontic elastomeric ligatures of a different manufacturer were evaluated.

Ardeshtna and Vaidyanathan [9] also found similar results, with the largest changes found in groups of tea and coffee, and the smallest color variation was also found in the group immersed in the cola solution. However, color changes caused by red wine were not investigated. Red wine, however, showed a strong effect on the coloration of the resin restorations in other studies [8, 14].

In restorative materials, staining by tea may be due to the adsorption of dyes on the material’s surface, which can be removed by brushing. On the other hand, staining by coffee may be due to both absorption and adsorption of dyes. This absorption and penetration of dyes is probably due to compatibility with the yellow dyes from coffee [15, 16]. In the esthetic orthodontic elastomeric ligatures, although coffee causes a higher colorings than tea [1, 9], there is no account

of the difference between adsorption and absorption of dyes in these materials.

Pigment absorption is potentially related to water retention and the resultant swelling of the polymer. The size of the surface and volume of samples can strongly influence the absorption of water, representing color variations of the elastomeric modules [9]. The studies by Ardeshna and Vaidyanathan [9] and Fernandes *et al.* [1] did not measure the esthetic orthodontic elastomeric ligatures themselves, but an area of the stem which joins the esthetic orthodontic elastomeric modular ligatures units, thus finding ΔE values higher than the ones found in the present study.

In the literature there is no consensus on the limits of chromatic variation that would be noticeable to the human eye. Most researches consider ΔE values greater than 3.3 visually noticeable, based on previous investigations [6, 17, 18]. In this study, the ΔE values for the groups immersed in distilled water were all $\leq 0,76$, regardless of the initial color, which are changes considered visually imperceptible. These results were similar to the ones by Soldati *et al.* [10], and indicate that water is a good means of control and can simulate the effect of saliva in the oral environment.

Although the ΔE values of samples immersed in Coca-Cola[®] are below 3.3, which would be clinically acceptable for resin restorations, the esthetic orthodontic elastomeric ligatures presented distinguishable color variations in comparison with the control group. This means that the value of 3.3, although suitable for restorative composites, cannot be considered a limit to the visibility of color variations when evaluating esthetic orthodontic elastomeric ligatures.

Regardless of the hue tested, all solutions exerted statistically significant influence when compared with the control group. These results demonstrate that esthetic orthodontic elastomeric ligatures are susceptible to pigmentation, as described by several authors [3, 9, 10, 19].

Esthetic orthodontic elastomeric ligatures are made by synthesis of polyurethane, which can be produced with different chemicals. The chemical alteration influences the configuration of the elastomeric chains and its ability to resist decay by external agents. The processing conditions can also affect the structure and configuration of the polymer chains. Furthermore, the surface characteristics, such as texture and porosity, may be different between manufacturers and influenced by external agents [1, 9, 20].

From a clinical point of view, the study has shown that the esthetic orthodontic elastomeric ligatures of all hues are prone to significant color changes. Orthodontists should be aware of the instability of the color of the esthetic orthodontic elastomeric ligatures, and plan a shorter time interval between appointments, in order to meet the esthetic needs of patients.

CONCLUSION

Among the substances evaluated, those that have a greater potential for staining the esthetic orthodontic elastomeric ligatures were black tea, wine and coffee, respectively. All shades of esthetic orthodontic elastomeric ligatures are susceptible to color change, with no statistically significant difference between the tested colors.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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