Force degradation and staining of aesthetic chain elastics when submitted to different phytotherapic rinses

Degradação forçada e coloração de elásticos de cadeia estética quando submetidos a diferentes enxaguamentos fitoterápicos

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ABSTRACT
The objective of this study was to evaluate the color (ΔE*) and the degradation of the strength of chain elastics when submitted to different rinses. Forty segments of aesthetics chain elastics (American Orthodontics) were maintained extended in distilled water at 37°C. The elastics (n=10) were immersed twice a day for 60 seconds each in the following solutions: Chlorhexidine Gluconate; Grapefruit essential oil; Ginger and distilled water. The readings were performed in the following times: initial, 24 hours, 7, 14, 21, and 28 days using universal testing machine and spectrophotometer. The force degradation data were analyzed by mixed models for repeated measurements in time, and the data from ΔE* were evaluated by Kruskal Wallis and Dunn and Friedmann and Nemenyi (α=5%). Except for the group immersed in Ginger, there was a significant decrease in force degradation after 24 hours ($p<0.05$); after 7 days there was force recovery for all solutions. For ΔE* it was found that there was no statistically significant difference between the solutions for most of the time. However, after 28 days Chlorhexidine showed less ΔE* than the other solutions. It is concluded that the time in which the elastic chain is stretched influences the degradation of strength; immersions in rinses with the exception of ginger solution degrade the strength after 24 hours and; there is color change for all solutions after 28 days.

Key-words: Color, Strength and Orthodontics, Introduction.

RESUMO
O objectivo deste estudo era avaliar a cor (ΔE*) e a degradação da resistência dos elásticos de cadeia quando submetidos a diferentes enxaguamentos. Quarenta segmentos de elásticos de cadeia estética (Ortodontia Americana) foram mantidos estendidos em água destilada a 37°C. Os elásticos (n=10) foram imersos duas vezes por dia durante 60 segundos cada, nas seguintes soluções: Gluconato de clorexidina; Óleo essencial de toranja; Gengibre e água destilada. As leituras foram realizadas nos seguintes tempos: inicial, 24 horas, 7, 14, 21, e 28 dias utilizando máquina de ensaio universal e espectrofotómetro. Os dados de degradação de força foram analisados por modelos mistos para medições repetidas no tempo, e os dados de ΔE* foram avaliados por Kruskal Wallis e Dunn e Friedmann e Nemenyi (α=5%). Com excepção do grupo imerso em Ginger, houve uma diminuição significativa da degradação da força após 24 horas ($p<0,05$); após 7 dias houve uma recuperação da força para todas as soluções. Para ΔE* verificou-se que não houve diferença estatisticamente significativa entre as soluções durante a maior parte do tempo. No entanto, após 28 dias, a clorexidina mostrou menos ΔE* do que as outras soluções. Conclui-se que o tempo em que a cadeia elástica é esticada influencia a degradação da força; imersões em enxaguamentos com excepção da solução de gengibre degradam a força após 24 horas e; há uma mudança de cor para todas as soluções após 28 dias.

Palavras-chave: Cor, Força e Ortodontia, Introdução.

1 INTRODUCTION

Currently, with the advent of aesthetic orthodontics, many orthodontic materials have been developed with the goal of offering aesthetics allied to orthodontic treatment (Lombardo et al., 2017) [[1]], however, many flaws are still observed in dental offices regarding the stability of these materials (Kumar et al., 2014) [[2]], since they are subjected to different oral cavity conditions (Ardeshna, 2009)[[3]].

Among these materials are the chain elastics, used, for example, for dental movements to close interdental spaces (Kumar et al., 2014) [[2]]. These elastics after the advent of aesthetic orthodontics had to adapt to this condition, becoming increasingly imperceptible at the time of installation (Aldrees et al., 2015) [[4]]. However, what is verified by studies is the change in color of these over time when subjected, for example, to commonly consumed food coloring substances (Aldress et al., 2015) [[4]] and the use of oral antiseptics, which creates discomfort for the patient and orthodontist (Ramachandraiah et al., 2017) [[5]].

Another negative point related to these elastomers is that despite the important role of force transmission, they are still not considered ideal materials as they present a relevant decline in force that may cause a clinical problem, since orthodontic treatments act on the strength of these accessories (Pithon et al., 2014) [[6]]. This gradual reduction in elastomer strength is linked to activation time, oral environment temperature, patient diet (Pithon et al., 2013)[[7]] and use of substances for oral hygiene (Pithon et al., 2013; Behnaz et al. 2017; Behnaz et al. 2018)[[7],[8],[9]].

Regarding oral antiseptics, these are widely used by patients with orthodontic appliances, since they are coadjuvants in sanitization and aim to reduce the rate of plaque in this population that presents higher levels of demineralization and, consequently, of white enamel stain, which occurs due to the difficulty of sanitization in the proximity of orthodontic appliances (Shah et al., 2019; Bauer Faria et al., 2020) [[10],[11]]. On the other hand, as mentioned above, the commercially available rinses have already been studied for their action on aesthetic elastics and it has been found that they can promote changes in color and strength of these elastics (Pithon et al., 2013) [[7]].

One of the most used antiseptics in dentistry is chlorhexidine (Losito et al., 2014; Bauer Faria et al., 2020) [12,[11]], which is not very toxic and presents substantivity (Zanatta and Rosing, 2007) [13] however, it presents side effects that make long-term use difficult (Charles et al. 2004; Raszewski et al. 2019; Bauer Faria et al., 2020) [14,15,[11]].

In this way, it becomes of extreme importance to study new formulations of phytotherapeutic oral rinses with the purpose of maintaining oral homeostasis and alter these aesthetic materials as little as possible (Larrabee et al., 2012) [16]. Thus, several natural antiseptics have been researched and developed, aiming to offer more benefits and less side effects (Shapiro et al., 2002; Habauzit and Morand, 2012, Santamaria et al., 2014; Bauer Faria et al., 2020) [17,18,19,[11]].

An example of this is the ginger essential oil-based mouth rinse, which was recently studied by this research group in order to analyze its action in the oral cavity, and it was found that it has representative anti-inflammatory property with an effect on reducing gum bleeding and is indicated for patients wearing orthodontic appliances (Bauer Faria et al., 2020) [[11]].

The essential oil of ginger extracted from the roots of the plant Zingiber officinale, is one of the most used spices in the world and has been highlighted for having strong antimicrobial, antifungal, and antioxidant activities (Silva et al., 2018) [20]. In the oral cavity, it has been used due to its action: healing; anti-inflammatory and antimicrobial (Grégio et al., 2006) [21]. The antimicrobial activity was verified on Gram-positive bacteria, as Streptococcus mutans (Azizi et al., 2015) [22], and Gram-negative (Grégio et al., 2006) [21], already the antifungal action against C. albicans (Aghazadeh et al., 2016) [23].

Grapefruit has also been widely studied and many benefits have been attributed to it, such as reducing the risk of hypertension (Habauzit and Morand, 2012) [18], and the presence of flavonoids improve other cardiovascular parameters (Khurana et al, 2013) [24] and decrease the release of pro-inflammatory substances, thus inducing an improvement in endothelial function (Paredes et al., 2018) [25], as well as the decrease of Streptococcus mutans biofilm formation during critical growth phases (Filoche, Soma and Sissons, 2005) [26].

However, no studies were found that evaluated the influence of these natural substances on chain elastics. Therefore, the analysis of this influence is of extreme importance, aiming to obtain mouthwash as effective as chlorhexidine and other oral antiseptics, but which have fewer side effects and can be used by patients in orthodontic treatment. Thus, the objective of this study was to evaluate the color (ΔE*) and the degradation of the strength of elastics in aesthetic chain when submitted to different rinses. The objective of this study is based on the hypothesis that color change and degradation of elastic strength aesthetic chain elastics would not be influenced by herbal rinses

2 MATERIAL AND METHODS

2.1 EXPERIMENTAL DESIGN

The experimental design evaluated the influence of oral rinsing factors (0.12% Chlorhexidine Gluconate; Grapefruit essential oil; Ginger essential oil; Distilled water control) and Time (T0-initial; T1-24 hours; T2-7 days; T3-14 days; T4-21 days; T5-28 days) on the response variables: color change and force degradation, obtained with the aid of the X-Rite spectrophotometer model SP62S (X-Rite Pantone, Grand Rapids, Michigan, USA) with QA Master model software and the EMIC universal testing machine (DL 200, EMIC, São José dos Pinhais, PR, Brazil), respectively.

For the research development, a pilot experiment was conducted to determine the number of specimens, standardize the technique of making the samples and tests. The sample of the experiment was constituted by 40 elastic segments (n=10). The materials used in this experiment are shown in Table 1.

Table 1: Materials used in the experiment

Material	Composition	Manufacturer
Chlorhexidine Gluconate 0.12%	0.12% chlorhexidine gluconate and water	Faculty of Pharmacy of FHO, Araras, SP.
Grapefruit essential oil solution (experimental)	Sodium Lauril Sulfate 1%, Sorbitol 20%, Polysorbate 80 1%, grapefruit essential oil 0.5%, saccharine 0.5%, 100ml distilled water q.s.q.	Faculty of Pharmacy of FHO, Araras, SP.
Ginger Solution (Bauer Faria et al., 2020)[11]	30g Laurel sodium sulfate ether, 14 ml sorbitol, 30 ml polysorbate 80, 10 ml ginger essential oil, 1 g saccharin, 2930 ml distilled water q.s.q.	Faculty of Pharmacy of FHO, Araras, SP.
Distilled water	Distilled water	Asfer Chemical Industry, São Caetano do Sul, SP, Brazil.

2.2 SPECIMEN PREPARATION

Orthodontic elastics were purchased in sealed packages and on expiration date. For this study 40 segments of aesthetic chain elastics (American Orthodontics, Sheboygan, Wisconsin, USA) were used in the average size. They were carefully sectioned in segments of 5 modules each, with initial length of 16 mm, ignoring the two ends of the segments, whose function was only to facilitate the lengthening of the elastics.

Four 11 cm long, 4 cm wide and 1 cm thick white acrylic plates were made (Solugrav, Tubarão-SC, Brazil). On these plates, laser perforations were performed at a depth of 5mm and in each hole, prefabricated plastic pins (Morelli, Sorocaba-SP, Brazil) were adapted and fixed with transparent self-curing acrylic resin (Jet, Campo Limpo Paulista/SP, Brazil), according to the protocol adaptation proposed by Kochenborger et al. [27].

Initially, for adaptation of the elastics on the plate and before the first reading, the elastics were pre-stretched in 50% of their length (De Aguiar et al., 2014) [28].

For this, a pliers type Palmer was used (Jon Comércio de Produtos Odontológicos, São Paulo, Brazil), which has a lock and allows the opening of exactly 50% more of the original length of the elastic (De Aguiar et al., 2014) [28].

2.3 IMMERSIONS

The plates were identified with the name of the respective solutions submitted: 0.12% Chlorhexidine Gluconate; Grape Fruit essential oil; Ginger essential oil; Distilled water - control. The specifications of each rinse are represented in Table 1.

The elastics were kept extended on the respective acrylic plates and kept immersed in distilled water at 37°C in an oven (model 002 CB, Fanem, São Paulo/SP, Brazil) during the entire experimental period, only being removed for immersion. Each acrylic plate was completely submerged together with the current elastics in the respective rinsing groups and control solutions for 60 seconds, twice a day, at 12-hour intervals from each other, according to the adapted methodology of Pithon et al. 2014 [6] After each immersion in the rinses, the plates were washed with distilled water.

2.4 COLOR AND STRENGTH READINGS

Force degradation, as well as color change, were evaluated as a function of lengthening time and immersion in rinse solutions. Analysis times corresponded to the initial - T0; 24 hours - T1; 7 days - T2; 14 days - T3; 21 days - T4 and 28 days - T5.

Regarding color readings, initially the elastics were supported on a white surface, duly standardized, for later reading with the aid of the X-Rite spectrophotometer model SP62S (Gran Rapids, Michigan, USA), which has a focal aperture of 4 mm in diameter and the diffuse geometry used of D/8°, it emits light with waves in the range of 400 to 700 nm on the object and measures the reflection of this spectrum. With the CIE L* a* b* system the color measurements were obtained. ΔE*, that is, the total difference between two color stimuli, was calculated by the following formula: $\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$.

The CIE L*a*b* system uses three parameters to define color: brightness, hue and saturation (Commission Internationale De L'eclairage, 1978). The luminosity represents the degree of light and dark of the object represented by the value of L*, being L* = 100 for white and L* = 0 for black.

The parameters a* and b*, called chromatic scale (hue), represent red if +a* and green if -a*, yellow if +b* and blue if -b* (Schulze et al., 2003) [29]. Saturation is the intensity of hue and is given by the numerical value of a* and b*. The values of ΔL*, Δa*, Δb*, correspond to the difference of the values of L*, a*, b*, respectively, in comparison to the initial pattern. Only the analysis of ΔE* was selected for the study.

The EMIC DL 500 MF universal testing machine (São José dos Pinhais, Paraná, Brazil) was used to read force degradation. It consists of a fixed base and a mobile base, prepared with hooks at the ends, to keep the elastics activated during the experiment and allow the reading of the magnitude of the forces released (Motta, Cury-Saramago and Nojima, 2011) [30]. The force degradation measurements were obtained by a single examiner, and each elastic segment was carefully transferred to the extension test mounted on the universal test machine in the times described (Losito et al., 2014) [12].

3 ANALYSIS OF RESULTS

Data on color change and force degradation were recorded and submitted to statistical analysis. The exploratory analysis indicated that the data of ΔE* do not present normal distribution, being applied nonparametric tests of Kruskal Wallis and Dunn (for comparisons between the rinsers) and Friedmann and Nemenyi (for comparisons between the times). The force degradation variable meets the assumptions of a parametric analysis being analyzed by mixed model methodology for repeated measurements in time. The analyses were performed in the R*(* R Core Team, Vienna, Austria, 2017) and SAS**(**SAS Institute Inc., Cary, NC, USA, 2011), considering the 5% significance level.

4 RESULTS

Table 2 shows the results of the color change analysis (ΔE*) according to the rinse and time. The group that was submitted to chlorhexidine presented greater variation in color (ΔE*) in 21 and 28 days of immersion than in 7 days ($p<0.05$). The groups that received mouth rinses with Grapefruit and Ginger extract had more ΔE* after 28 days than after 24 hours and 7 days ($p<0.05$). The group immersed in distilled water presented higher ΔE* after 28 days when compared to 24 hours, 7 and 14 days. After 28 days of immersion, a greater variation in color (ΔE*) was observed in the group immersed in distilled water than in those immersed in chlorhexidine ($p<0.05$).

Table 2. Median (minimum value; maximum value) of the color change (ΔE*) according to the rinse and time

Rinse	Time				
	24 hours	7 days	14 days	21 days	28 dias
chlorhexidine 0,12%	2,25 (0,72; 3,29) ABa	1,64 (0,79; 3,61) Ba	2,02 (1,51; 4,31) ABa	3,02 (1,66; 4,87) Aa	2,97 (2,21; 4,76) Ab
Grapefruit essential oil solution	1,45 (0,40; 1,93) Ba	1,07 (0,56; 2,91) Ba	1,93 (0,99; 3,83) ABa	2,23 (0,49; 2,41) ABa	3,62 (2,09; 5,10) Aab
Ginger Solution	1,34 (0,40; 4,08) Ba	1,52 (0,57; 3,00) Ba	1,58 (1,01; 4,92) ABa	2,34 (1,37; 4,11) ABa	3,63 (1,90; 5,63) Aab
Distilled water	1,34 (0,19; 1,91) Ba	1,50 (0,76; 3,10) Ba	2,20 (0,86; 5,74) Ba	2,46 (1,66; 4,28) ABa	4,55 (3,74; 5,43) Aa

Medians followed by different letters (upper case horizontal and lower case vertical) differ from each other (p≤0,05)

Table 3 shows the results of force degradation as a function of time. With the exception of the group immersed in ginger, there was a significant decrease in degradation after 24 hours (p<0.05). With 7 days, there was a significant increase in the values found for all rinsers (p<0.05), maintaining until 28 days (p>0.05).

Table 3 - Mean (standard deviation) of force degradation (g) as a function of rinsing and time

Rinse	**Time**					
	Initial	**24 hours**	**7 days**	**14 days**	**21 dias**	**28 dias**
Clorexidina	153,00 (12,55) Aa	135,80 (6,00) Ba	154,30 (9,94) Aa	151,60 (7,69) Aa	157,40 (6,17) Aa	160,50 (6,28) Aa
Grapefruit Extract	155,50 (9,54) Aa	130,60 (10,35) Ba	163,70 (11,60) Aa	157,90 (9,76) Aa	169,50 (12,54) Aa	167,50 (9,00) Aa
Ginger	147,5 (7,96) ABa	133,90 (11,74) Ba	156,30 (8,94) Aa	160,90 (11,21) Aa	161,80 (13,59) Aa	165,50 (12,76) Aa
Distilled water	157,10 (8,17) ABa	133,20 (6,75) Ca	153,90 (10,24) ABa	154,50 (7,76) Ba	168,20 (9,02) Aa	165,40 (11,66) ABa

Means followed by different letters (upper case horizontal and lower case vertical) differ from each other (p≤0,05).Discussion

Many factors can influence the strength and color degradation of chain elastics, especially aesthetics, including material manufacture, immersion medium, temperature, hydrogen potential (pH) and type of study (*in vitro* or *in vivo)* (Omidkhoda et al., 2015) [[31]]. Thus, this study aimed to evaluate the strength degradation and color of an aesthetic chain elastics when submitted to oral herbal rinses (ginger- Zingiber officinale and Grapefruit Extract) comparing them to chlorhexidine gluconate 0.12%, as a function of time.

For the study, the immersion time in oral rinses of 3 min per day for 5 days per week for 28 days was used to simulate the time these substances stay in contact with the oral cavity (Godoi et al., 2011) [[31]]. In the intervals of immersion, the elastics were kept distended and immersed in distilled water at a temperature of 37ºC, simulating the body temperature, as this influences the degradation of force (Hwang and Cha, 2003) [[33]].

The null hypothesis of the study that color change and strength degradation of the aesthetic chain elastics would not be influenced by herbal rinses was rejected. It was found in this study that there was a decrease in initial strength after 24 hours of immersion in the rinses, which is in accordance with the study of Kanchana and Godfrey (2000) [[34]], Weissheimer et al., 2013 [[35]] and Omidkhoda et al. 2015 [[31]], who found that there is a remarkable degradation of elastics strength studied when subjected to immersion in water, approaching 30% during the first hour, but with an average loss of less than 7% up to 3 days. The decrease in initial strength may be due to three main factors: solubility due to lixiviation of constituents, swelling due to water absorption and cracks due to wear, due to the environment (Kanchana and Godfrey, 2000) [[34]].

After the first 24 hours, analyzing the elastics in up to 7 days there was a discrete recovery of forces, a factor not yet known, but which may be the result of a time-dependent reorganization of the polymeric chains broken after stretching (Liu, Wataha and Craig, 1993) [[36]].

Such results were also found by Liu, Wataha and Craig (1993) [[36]] and Moris et al. (2009) [[37]], but different from other articles such as those by Kochenborger et al. (2011) [27] and Larrabee et al. (2012) [16]. This difference between studies may be due to differences in methodology, as well as the brand of the elastic studied, since it is known that the manufacturing process of elastics, as well as their compositions influence the degradation of forces (Behnaz et al., 2017) [[8]].

Moreover, it was found that there were no differences in the degradation of forces of these aesthetic chain elastics, when the different oral rinses were compared in their respective times, making these phytotherapics possible choices for use as oral antiseptic (Javanmardi and Salehi, 2016) [[38]] during orthodontic treatment. Although the action of phytotherapeutic rinses containing ginger or grapefruit extract on orthodontic elastics was not found in the literature, a study by Phiton et al. (2013) [[7]] evaluated the degradation of elastic forces when submitted to chlorhexidine in different concentrations and also found that chlorhexidine in 24 hours and 7 days does not promote a statistically significant difference in distilled water (control) on this property. This increases the range of products that can be used as coadjuvants without great harm to the elastic properties of these orthodontic devices, complementing the recent findings of this research group (Bauer Faria et al., 2020) [[11]] regarding the use of ginger in oral rinse formulation for use by patients with orthodontic appliances.

In relation to ΔE* (total difference of color stimuli) it was verified that after 24 hours, 7 days and 14 days there was no statistically significant difference between the groups submitted to the different mouth rinses, however, at 21 days, it was noted that grape fruit extract changed less the color of the elastics than the other rinses. After 28 days, the group submitted to 0.12% chlorhexidine showed less color change than distilled water, although there was no statistically significant difference between this and the groups that used the other two herbal rinses.

Although there was no difference in color between the times, there was color alteration of the elastics, which corroborates with the *in vivo* study by Kawabata et al. (2016) [[39]], who also demonstrated that after 30 days of using the elastics in the mouth, there is color alteration. The literature considers three different intervals for classifying color changes as clinically acceptable or not: ΔE*<1, imperceptible to the human eye; 1.0<ΔE*<3.3, seen only by experienced people in the field, but still considered clinically acceptable; and ΔE*>3.3, easily observed, that is, it is clinically unacceptable (Vichi et al., 2004; Ruttermann et al., 2010; Ceci et al., 2017) [[40],[41],[42]]. Therefore, the color change found in this study after 7 days of immersion of the elastic in the solutions studied, is considered clinically acceptable, although perceived by experienced people in the area, already after 28 days of experiment, this color change is considered clinically unacceptable.

It was also observed that at 28 days the elastics submitted to chlorhexidine showed less color change than the elastics submitted to control solution. This staining pattern was also observed in the study by Silva et al. (2011) [43], who, although they did not evaluate elastics but rather polymeric restorative materials, observed that distilled water in most of the cycles evaluated in their studies promotes greater color changes than disinfectant solutions. The authors report that disinfectant solutions contain lower volumes of water and therefore cause less color changes than distilled water, since polymeric materials suffer sorption of water and, consequently, the larger the amount of water the greater the color change (Yiu et al., 2004) [44]. This sorption can eventually cause irreversible damage to materials due to the formation of micro-cracks as a result of repeated sorption/desorption cycles, which are followed by hydrolytic degradation of the polymer with the splitting of the ester bonds and gradual deterioration of the polymer infrastructure over time (Yiu et al., 2004) [44]. This phenomenon can contribute to forming zones with different optical properties (Devlin et al. 2005) [45] that can be considered aesthetically unacceptable (Silva et al., 2011) [43].

It can be said that a limitation of this study is the fact that it is an *in vitro* study because it is known that this type of experiment presents limitations in the behavioral evaluation of dental materials, since the real oral condition, related to the presence of the food cake, the amount of food intake among other situations, has direct action on the physical-mechanical behavior of these materials (Aldrees et al., 2015) [[4]]. However, experimental studies in laboratories allow verification of the longevity of the materials and their clinical behavior, in addition to providing guidance to patients on the best way to preserve the aesthetics initially offered by the chain elastics installed.

5 CONCLUSION

It is concluded that only in the solution with ginger essential oil there was no degradation of strength in the first 24 hours, and that in all solutions there was significant change over time, regarding the color of this chain elastic studied.

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