

In vivo color changes of esthetic orthodontic ligatures

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Objective: To assess the color changes that occur in four commercial brands of esthetic orthodontic elastomeric ligatures after exposure to the oral environment. **Methods:** The four elastomeric ligatures manufacturers mostly mentioned by orthodontists were investigated: Morelli, Uniden, American Orthodontics (AO) and TP. The sample comprised 25 patients. The elastomeric ligatures were randomly distributed and arranged in the four dental quadrants of each patient, r for 30 days. After this period, two units of each brand were photographed in a standardized manner. Subsequently, color changes were visually evaluated and assigned a score (0, 1, 2 or 3) by a panel of four examiners. The mean scores assigned by the examiners were statistically analyzed by ANOVA and Tukey's test ($p < 0.05$). **Results:** The mean pigmentation scores assigned to Morelli (1.80 ± 0.78) and Uniden (1.92 ± 0.66) elastomeric ligatures after 30 days in the oral environment were not statistically different. However, these brands were significantly more pigmented after 30 days in the oral environment ($p < 0.01$) compared to American Orthodontics (0.97 ± 0.6) and TP (0.83 ± 0.79). **Conclusions:** Although all four brands exhibited an undesirable pigmentation after 30 days in the oral environment, color change for American Orthodontics and TP Orthodontics ligatures was significantly lower than Morelli and Uniden products.

Keywords: Elastomeric ligatures. Pigmentation. Visual perception.

Objetivo: avaliar as alterações de cor ocorridas em elastômeros estéticos de quatro marcas comerciais, quando expostos ao meio bucal. **Métodos:** foram examinadas as quatro marcas comerciais mais citadas por ortodontistas – Morelli, Uniden, American Orthodontics (AO) e TP –, em 25 pacientes consecutivos. Os elastômeros foram distribuídos de forma aleatória e ordenados nas quatro hemiarcadas de cada paciente, permanecendo no meio bucal por 30 dias. Após esse período, duas unidades de cada marca em todos os pacientes foram fotografadas de forma padronizada para, posteriormente, serem analisadas através de avaliação visual quanto à variação de cor, por escores (0, 1, 2, 3), por um painel de quatro examinadores. Os escores médios dos examinadores foram analisados estatisticamente por meio da ANOVA e teste de Tukey, com $p < 0,05$. **Resultados:** os escores médios de pigmentação, após 30 dias no meio intrabucal, obtidos para os elastômeros Morelli ($1,80 \pm 0,78$) e Uniden ($1,92 \pm 0,66$) não foram estatisticamente diferentes entre si. Entretanto, essas marcas estavam significativamente mais pigmentadas após 30 dias no meio intrabucal ($p < 0,01$) quando comparadas às marcas importadas, American Orthodontics ($0,97 \pm 0,6$) e TP ($0,83 \pm 0,79$). **Conclusão:** apesar de todas as quatro marcas apresentarem uma indesejável pigmentação após 30 dias no meio intrabucal, as marcas American Orthodontics e TP apresentaram alterações de cor menos significativas do que as marcas Morelli e Uniden.

Palavras-chave: Elastômeros. Pigmentação. Percepção visual.

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INTRODUCTION

Advances in cosmetic dentistry and the increasing demand for orthodontic treatment for adult patients have compelled the industry to release increasingly esthetic and less conspicuous orthodontic appliances. Brackets bonded to the lingual surface of the teeth, clear aligning systems, esthetic brackets made from polycarbonate, composite, ceramics or sapphire, illustrate some of the products released by the industry in order to satisfy the esthetic needs of these patients.

Although the quality of these materials is thoroughly tested before clinical use, clinical orthodontists have found that some of these products undergo a number of changes in their properties, especially changes in color due to staining by food or by contact with oral fluids. Concerns have been raised about the quality of these products and whether one particular company might be superior to another in terms of efficiency or cost-effectiveness. Many studies have evaluated the effects of the oral cavity on the elastic properties of elastomeric ligatures, such as force decay, friction and dimensional changes.¹⁻⁷ However, researchers have shown little concern about the behavior of orthodontic materials after exposure to the oral environment, especially the extent to which these changes interfere with esthetics.

Ceramic brackets have gained increased popularity in orthodontic treatment over the last decades mainly due to color stability. A frequent complaint of orthodontists and patients regards color changes in the elastomeric modules used to tie orthodontic archwires to ceramic brackets.

Prolonged exposure to cola soft drinks is a proven cause of color changes in restorative composites, while spices and seasonings can cause extrinsic stains to the teeth.^{8,9} In orthodontics, some laboratory studies have shown that light-colored elastomeric ligatures show color changes after immersion in liquids with high pigmentation capacity.¹⁰⁻¹² Since these studies were conducted *in vitro*, they may not account for numerous other factors present in the oral environment that could contribute to color changes, such as the oral flora, the mechanical effect of brushing, solid and semi-solid foods, which can also stain, among many others. Thus, it seems quite obvious that an *in vivo* study can yield a more realistic analysis of actual color changes taking place in orthodontic materials after clinical use.

OBJECTIVE

Analyze color changes in esthetic elastomeric ligatures provided by four different manufacturers after a one-month exposure to the oral environment by a visual analysis.

MATERIAL AND METHODS

This study evaluated four brands of esthetic orthodontic elastomeric ligatures: Morelli – Lot 1268512 (Sorocaba, Brazil), Uniden – Lot 040209-E1-4 (Sorocaba, Brazil), American Orthodontics – Lot 00182559 (Sheboygan, Wisconsin, USA) and TP – Lot 1419028 (La Porte, Indiana, USA). The elastomeric modules were used in 25 consecutive patients undergoing orthodontic treatment in the Specialization Course in Orthodontics, ABO-Pará State, Brazil. These brands were selected after a survey was conducted with 100 Brazilian orthodontists via e-mail. Forty-four dentists (44%) responded to the following question: Which elastomeric ligature do you use on esthetic brackets? Two respondents reported that they were not using esthetic brackets. Two Brazilian and two American manufacturers most cited by the remaining 42 orthodontists were utilized. The brands cited in this research were:

- » Morelli (Sorocaba, São Paulo, Brazil): 10.
- » Uniden (Sorocaba, São Paulo, Brazil): 2.
- » TP (La Porte, Indiana, USA): 8.
- » American Orthodontics (Sheboygan, USA): 11.
- » GAC (Bohemia, NY, USA): 6.
- » 3M Unitek (St. Paul, Minnesota, USA): 3.
- » Orthosource (North Hollywood, USA): 1.
- » Tecnident (Porto Alegre, RS, Brazil): 2.

A split-mouth, randomized, triple blind study design was employed. In each patient, the four brands were distributed by quadrant in random and ordered fashion (Fig 1), remaining in the oral environment for a period of 30 days.

The subjects participating in the research were not on any specific type of diet. After 30 days, the ligatures were removed from the oral environment, separated by quadrant, and the brands were identified by numbers. Two ligatures – used on the anterior teeth of each quadrant – were selected for analysis.

Forty two photographs (25 original and 17 duplicates) were obtained using a digital camera model Canon EOS Rebel XTi (Canon, Osaka, Japan) with

10 megapixels resolution and color depth of 12 bits (Fig 2). All photographs were taken manually by a single operator, with 1/6 seconds speed, 22 diaphragm aperture, ISO 200, without flash, self-timer mode set to trigger after 10 seconds, images stored in JPEG format. A Sigma DG 105 mm (Ronkonkoma, NY, USA), 2.8 macro lens was used in an environment with total absence of daylight, lighted by two 110W halogen lamps, positioned at a fixed distance of 16 cm from each other, according to the method described previously.¹¹

The photographs were evaluated at two times: Before use (T_1) and after 30 days in the oral environment (T_2).

In order to carry out a visual analysis of the elastomeric ligatures, a PowerPoint presentation (Microsoft, Redmond, WA, USA) was created comprising 25 original photographs and 17 duplicates, randomly arranged. The images were assessed independently by a panel of four orthodontists who rated the degree of pigmentation of the elastomeric ligatures in each quadrant using a numerical scale ranging from 0 (zero) to 3, where 0 was assigned to unpigmented

ligatures, 1 was assigned to slightly pigmented ligatures, 2 to moderately pigmented ligatures, and 3 to heavily pigmented ligatures. All ligatures were ranked and grouped accordingly. The photographs of the ligatures prior to use were presented to a single blinded examiner to determine the initial score.

Statistical analysis

The data obtained from the reproducibility test were tested using the Wilcoxon test. The brands were compared by means of statistical analysis using the mean scores of the four examiners for each brand, after assessing the reproducibility of each examiner's diagnosis. The data were statistically compared by ANOVA and Tukey's test. All statistical analyses were examined at a significance level of 0.05 (5%).

RESULTS

The reproducibility test failed to reveal any significant differences for any of the examiners in the test-retest analyses (Table 1).

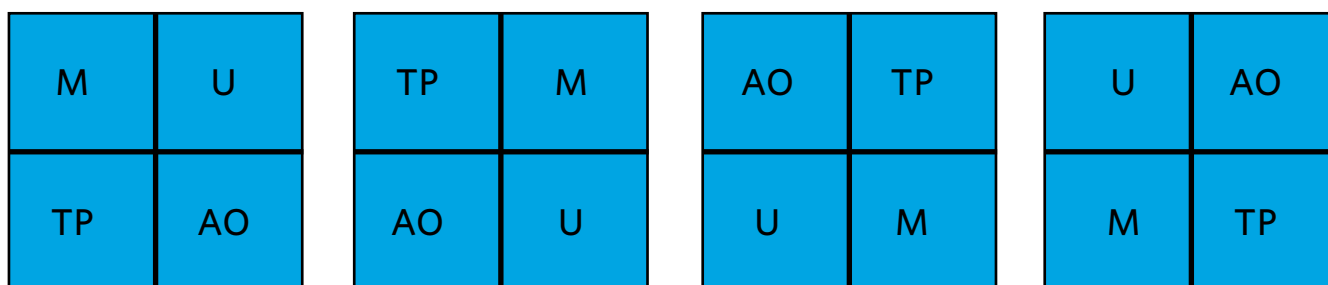


Figure 1 - Random, ordered distribution of brands by quadrant. (M = Morelli, U = Uniden, AO = American Orthodontics, TP = TP Orthodontics).

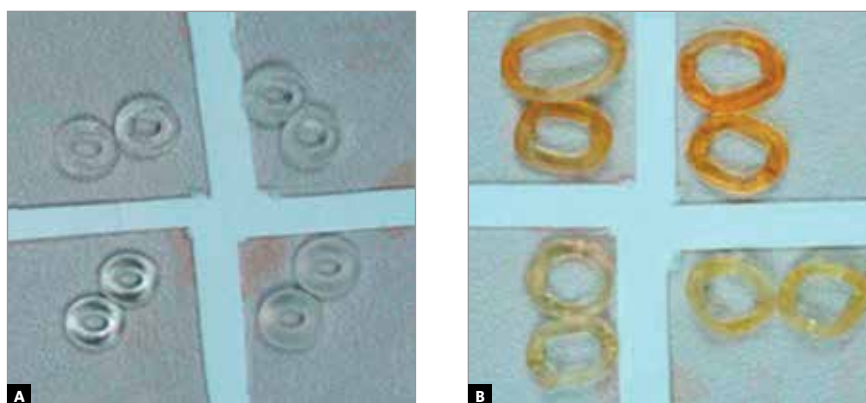


Figure 2 - Photographs of elastomeric ligatures at T_1 (A) and T_2 (B).

An analysis of the elastomeric ligatures before insertion in the mouth yielded a zero (0) score for all specimens examined (five in each group). Variance analysis showed that statistically significant differences were found between the commercial brands of elastomeric ligatures examined after 30 days of exposure to the oral environment ($p < 0.0001$). Tukey's test showed that the Brazilian brands (Morelli and Uniden) were similar, but significantly more pigmented (Fig 3, Table 2) than the US brands (American Orthodontics and TP).

DISCUSSION

Changes in the color of orthodontic ligatures have been performed by *in vitro* laboratory studies,¹⁰⁻¹² whereas the literature reports no *in vivo* analysis of

such color changes. This study, therefore, provides results that are closer to reality by assessing color changes in elastomeric ligatures after exposure to the oral environment.

Assessments of the physical properties of elastomeric ligatures have reported significant changes in the structure and composition of these materials after exposure to the oral environment.¹⁻⁷ Variations in the friction force of elastomeric ligatures of different brands were observed after immersion in laboratory solutions in an attempt to reproduce the oral environment.³ After exposure to the oral environment for 3 weeks and subsequent analysis by optical microscopy and spectroscopy, the elastomeric ligatures exhibited precipitates of calcium and phosphorus with the formation of calcium phosphate on the surface. A significant change was found in the structure and composition of the surface of the elastomeric ligatures after exposure to the oral environment, indicative of the severity of changes that can occur in the properties of these materials.⁴

In assessing the color, laboratory investigations were performed in an attempt to find differences in the staining of these elastomeric ligatures after immersion in different solutions. In these investigations, the change in color was measured quantitatively by means of a visual analog scale¹² or computational analyses.^{10,11} The results indicated that certain substances stain more than others, such as methylene blue and red pepper sauce.^{10,11}

Although a visually perceptible color change value was reported,¹¹ the equipment used in the research features considerable optical sensitivity and can be influenced by luminance and color of the surface on which the elastomeric ligatures are examined. Furthermore, one cannot determine to what extent color variations can compromise the visual esthetic pleasantness of an elastomeric ligature.

In the present study, a visual comparison between the four brands examined after 30 days in the oral environment was conducted by a group of four examiners using scores, disclosing significant differences between the brands tested ($p < 0.01$). Brazilian brands (Morelli and Uniden) had a similar, but poorer performance when compared to US brands (American Orthodontics and TP) which, also showed similar staining among each other (Table 2).

Table 1 - P values of reproducibility test (Wilcoxon) for the scores assigned by the four examiners using the visual method for Morelli, Uniden, American Orthodontics (AO) and TP Orthodontics brands.

Brand	p value Exam. 1	p value Exam. 2	p value Exam. 3	p value Exam. 4
Morelli	0.3173	1	0.3173	1
Uniden	0.593	1	0.3613	0.3173
AO	0.6858	0.6858	0.2367	0.593
TP	1	0.6858	1	1

Table 2 - Descriptive statistics and Tukey's test comparing the commercial brands of elastomeric ligatures examined, $F = 14.83$, $p < 0.0001$ (different letters, $p < 0.01$).

Brand	Mean	SD	Tukey
Morelli	1.80	0.78	A
Uniden	1.92	0.66	A
AO	0.97	0.60	B
TP	0.83	0.79	B

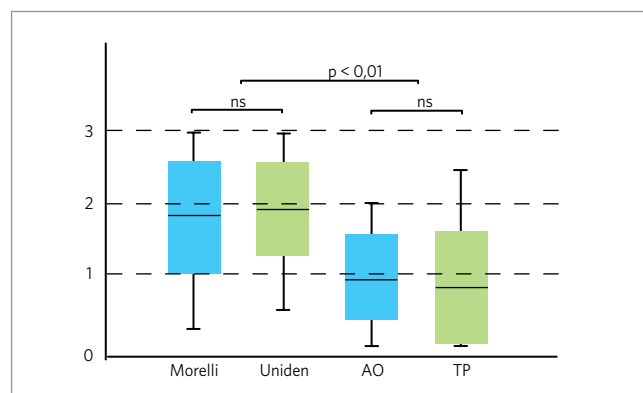


Figure 3 - Comparison between the examined elastomeric commercial brands, $F = 14.83$, $p < 0.0001$.

The visual analysis developed in this study allowed a direct comparison of the four most used brands according to a questionnaire answered by e-mail prior to the study. The results addressed a very common issue among orthodontists, that is which brand ensures for the patient greater esthetic stability during the period between two orthodontic maintenance visits. Previous attempts were made to examine the results with spectrometry (Minolta)¹⁰ and through an analysis of photographs with Adobe Photoshop software version 10.0 (Adobe System Inc., San Jose, California, USA).¹¹ However, the results showed a high variability in the test-retest examination, especially spectrophotometry, due to limitations inherent in the technique, which requires a relatively large area for color analysis. Additionally, such analysis can be influenced by the curvature of elastomeric ligatures, as mentioned previously.¹¹

Wide variations in the behavior of elastomeric ligatures of the same brand were observed in different patients (Fig 1). This may be due to a different diet and/or different oral hygiene habits, which

may have interfered with the degree of pigmentation exhibited by elastomeric ligatures during the experiment. Studies that correlate diet and elastomeric pigmentation between experimental groups could be conducted to determine the types of foods that contribute more significantly to the esthetic degradation of elastomeric ligatures.

Based on the results, manufacturers of orthodontic materials – Brazilian companies in particular – should modify manufacturing methodology to enhance the stability of light-colored elastomeric ligatures used on ceramic brackets. This achievement would meet the needs of the adult population currently seeking orthodontic treatment with increasing esthetic concerns.

CONCLUSIONS

The results revealed that all four brands exhibited an unwanted pigmentation after 30 days of exposure to the intraoral environment, although the US brands American Orthodontics and TP Orthodontics showed less pigmentation than Morelli and Uniden.

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