Frontiers in Dentistry

Color Stability of Orthodontic Elastomeric Ligatures in the Oral Environment: A Clinical Trial

Marzieh Mazhari[1], Mehdi Yaghoubi Ashrafi[1], Sara Gholamian[2], Mehrnaz Moradinejad[1]*

1. Department of Orthodontics, School of Dentistry, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
2. Private Practice, Ahvaz, Iran

Article Info

Article type:
Original Article

Article History:
Received: 17 Dec 2023
Accepted: 22 May 2024
Published: 13 Jan 2025

**** Corresponding author:***
Department of Orthodontics, School of Dentistry, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

Email: moradinejad-m@ajums.ac.ir

A B S T R A C T

Objectives: Despite the recent advances in orthodontic appliances, color change of elastomeric ligatures over time remains a problem causing patient dissatisfaction. This study aimed to assess the color stability of different types of orthodontic elastomeric ligatures in the oral environment.

Materials and Methods: This clinical trial was conducted on 67 patients. After applying the exclusion criteria, 11 participants were excluded, and 56 remained. Four different brands of elastomeric ligatures namely Ortho Technology, Ortho Organizers, American Orthodontics, and SIA were randomly used in the four quadrants of each patient (n=14 from each brand). Discoloration of ligatures was scored in the oral cavity by orthodontists and patients on the day of placement (T0) and 28 days later (T1). Photography and CIE L*a*b* color space were used to assess the color change (ΔE). Data were analyzed by the Kruskal-Wallis and Bonferroni tests.

Results: All brands showed discoloration. The highest ΔE was identified in SIA and Ortho Technology, while the lowest was recorded in Ortho Organizers. The lowest Δb (yellowness) and the greatest reduction in L* (lightness) and Δa (redness) were observed in Ortho Organizers. According to the opinion of patients and orthodontists at T0 and T1, SIA was the least visible followed by Ortho Technology. No significant difference was found between orthodontists and patients at T0 and T1 regarding the visibility of ligatures (P>0.05).

Conclusion: After 28 days, all brands of elastomeric ligatures showed considerable discoloration. Ortho Organizers showed the highest color stability.

Keywords: Color; Ligation; Orthodontics

➢ **Cite this article as:** Mazhari M, Yaghoubi Ashrafi M, Gholamian S, Moradinejad M. Color Stability of Orthodontic Elastomeric Ligatures in the Oral Environment: A Clinical Trial. *Front Dent.* 2025:22:03. https://doi.org/10.18502/fid.v22i3.17542

INTRODUCTION

Synthetic elastomeric materials including elastomeric ligatures were introduced to the market in 1960s for engagement of archwires in orthodontic brackets. Elastomeric ligatures are made of polyurethane with a unique composition not disclosed by the manufacturers [1-3]. Nonetheless, elastomeric ligatures have some limitations similar to other orthodontic appliances. Most relevant available studies have focused on disinfection of elastomeric chains [4], their tensile strength [5], and frictional forces [6]. Despite the recent advances in orthodontic appliances, color change over time is one of the main factors causing patient dissatisfaction. The main advantages of ligatures are fast application, patient comfort, and color variety. However, discoloration in the oral environment within a

few days after installation causes patient dissatisfaction, and calls for investigations to address this problem.

The space between the wire and elastomeric ligatures can serve as a suitable location for colonization of microorganisms [7]. The accumulated microorganisms contribute to discoloration by releasing chemical substances [8]. Also, the initial color of elastomeric chains and consumption of colored foods and drinks can affect the color change of elastomeric ligatures [9]. Despite the manufacturers' efforts to improve resistance to color change, the influence of the oral environment on ligatures is inevitable, mainly because of the ongoing change in the oral environment during the course of orthodontic treatment [10].

Spectrophotometers and calorimeters are commonly used for assessment of discoloration. However, due to the curvy shape of the ligatures, such measurement tools may experience errors in their color assessment, which is called "edge-loss error" [11,12]. In addition, previous studies showed a high correlation between spectrophotometry and digital camera in all CIE L*a*b* coordinates [13,14].

Limited information is available about accurate perception of color change of elastomeric ligatures by patients [11,15,16]. Due to the importance of esthetics and color in dentistry, this study aimed to evaluate the color change of four widely used elastomeric ligatures by computer analysis and colorimetry using the CIE L*a*b* color space. This system is commonly used to determine slight color differences. The advantage of this system for color assessment is that it strongly reflects the human sensitivity to colors. This method depends on the observer's perception of color and measures three color coordinates of L*, a*, and b* [1,16]. Thus, this study aimed to assess the color stability of different types of orthodontic elastomeric ligatures in the oral environment. Also, the four quadrants were compared to find out which quadrant shows more discoloration.

MATERIALS AND METHODS

Study design:

This clinical trial was ethically approved by the Ethics Committee of Medical Sciences (IR.AJUMS.REC.1398.694) and registered in the Iranian Registry of Clinical Trials (IRCT20200815048409N1).

Sample size:

The sample size was calculated to be 54 patients (~14 in each group) according to a study by Wee et al, [17] using the following formula:

$$\begin{cases} p_1 = 15.734 \pm 12.47 \\ p_2 = 12.554 \pm 10.86 \end{cases}$$

$$N = \frac{(z_{1-\alpha_4}+z_{1-\beta})^2(S_1^2+S_2^2)^2}{(\bar{X}_1-\bar{X}_2)^2} = 213$$

$z_{1-\alpha_4}$=1.96 for 95% confidence interval

$z_{1-\beta}$ =0.81 for 80% power

213÷4 ~ 54 number of total patients

In order to evaluate the color stability of elastomeric ligatures, four brands, including Ortho Technology (pearl; Tampa, FL, USA), Ortho Organizers (pearl; CA, USA), American Orthodontics (explicit; WI, USA), and SIA (clear; Caserta, Italy) were assessed 28 days after installment. It is important to note that both the patients and examiner were blinded to the brand of ligatures. All patients had to have three anterior teeth in each quadrant. Patients with a history of a systematic disease and those on a specific diet were excluded from the study. There was no age or gender restriction.

A total of 67 patients were initially selected; based on the exclusion criteria, 11 were excluded, and 56 remained in the study (14 in each group). As mentioned earlier, the total number of ligatures was calculated to be 213 (54 from each brand). Four ligatures (one from each brand) were used in each patient. Thus, 54 patients were enrolled. The patients were randomly divided into four groups through random allocation software. The permuted block randomization was used to balance the number of samples assigned to each group. Elastomeric ligatures with a predetermined random pattern were placed on the anterior teeth in the four quadrants (one from each brand) (Figure 1).

Assessment of color change:

The color change of elastomeric ligatures was assessed by both patients and orthodontists (n=4) at T0 (immediately after placement) and T1 (28 days later) under similar lighting.

OO	AO
SIA	OT

SIA	OO
OT	AO

OT	SIA
AO	OO

AO	OT
OO	SIA

Fig.1. Random distribution of ligatures by quadrant; OT: Ortho Technology; OO: Ortho Organizers; AO: American Orthodontics

conditions. In terms of visibility, elastomeric ligatures were scored using a 4-point scale from 1 indicating the lowest visibility to 4 indicating the highest visibility. Staining of ligatures was also scored using a 4-point scale as follows: 1 = no staining, 2 = slightly stained, 3 = moderately stained, and 4 = heavily stained.

Computer analysis and colorimetry using CIE L*a*b* color space:

For assessment of color change using CIE L*a*b* color space, the elastomeric ligatures were removed and transferred to separate containers coded by tooth number and stored in mucosamin solution (Professional Mucosamin Spray, Mucosamin company, England) until photography. After 24 hours, the samples were washed with distilled water for 1 minute and dried. They were then placed against a white background with a 18% gray card at 90-degree angle relative to the camera. The samples were photographed by a Nikon D90 digital SLR camera with 105mm focal range (12.3MP) and a 10-second self-timer by the same operator. To prevent light reflection, the light source indirectly illuminated the samples (Figure 2).

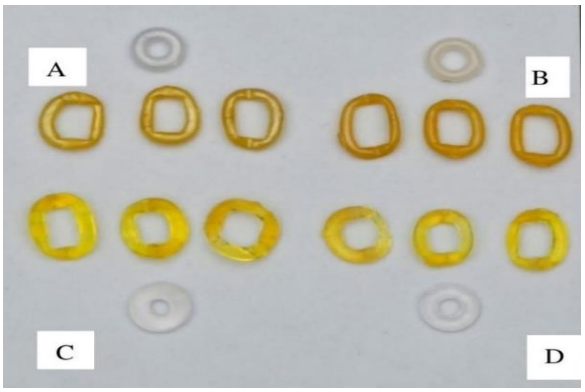

Fig 2. Photographed elastomeric ligatures at baseline and after 28 days; A: American Orthodontics, B: Ortho Organizers, C: Ortho Technology, D: SIA.

Photoshop 2018 software was used for colorimetry and image processing. First, four parts of each elastomeric ligature were selected. Isolation was performed to determine the color of the upper, lower, left, and right parts of each ligature. The L*, a*, and b* color parameters of all four brands of elastomeric ligatures were measured. Accordingly, the color change (ΔE) was calculated using the following formula:

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

Where L* indicates lightness, a* indicates redness/greenness with +a representing redness and -a representing greenness, and b* indicates yellowness/blueness with +b representing yellowness and -b representing blueness. The ΔE of each specimen as the total discoloration was then calculated [1,15]. Color measurements were made before and after immersion in mucosamin solution.

Statistical analysis:

The normality of data distribution was analyzed by the Kolmogorov-Smirnov test. Accordingly, the Kruskal-Wallis and Bonferroni tests were used for general and pairwise comparisons of different brands, respectively, with 95% confidence interval. The Chi-square test was applied to compare the perception of patients and orthodontists regarding discoloration of ligatures. All analyses were carried out at 0.05 level of significance.

RESULTS

Of a total of 67 initially screened patients, 56 (83.68%) remained in the study. No significant difference was found between the evaluation performed by patients and orthodontists at T0 and T1 (P>0.05). American Orthodontics and Ortho Organizers had the highest visibility (scores 3 and 4, respectively). The median value for American Orthodontics and Ortho Organizers was 3, while the median value for Ortho Technology and SIA was 2. Figure 3 shows the median and inter-quartile range for the visibility score of ligatures reported by orthodontists and patients at T1.

Table 1 presents the measures of central dispersion for ΔE. The four brands had a significant difference regarding ΔE (P<0.001).

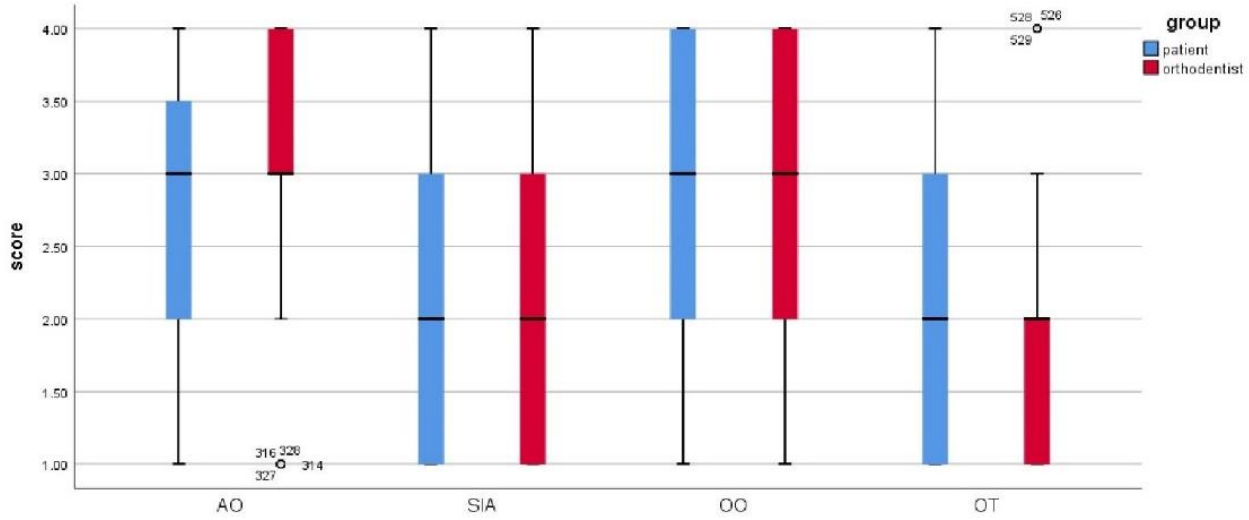

Fig 3. Visibility score of ligatures reported by orthodontists and patients at T1; OT: Ortho Technology; OO: Ortho Organizers; AO: American Orthodontics

Table 1. ΔE and P values for different brands

Group	ΔE				P
	Mean ±SD	Minimum	Maximum	Mean Rank	
Ortho Technology	70.28±11.49	41.02	85.47	150.86	<0.001
Ortho Organizers	51.34±7.17	36.18	64.58	53.91	
SIA	72.12±9.92	39.12	82.23	160.18	
American Orthodontics	57.56±8.95	40.15	71.01	85.05	

SD: standard deviation

The highest ΔE was observed in SIA followed by Ortho Technology. Among all brands, Ortho Organizers followed by American Orthodontics showed the highest color stability. The Δa, Δb, and ΔL changed after 28 days (Table 2). The highest mean ΔL was noted in Ortho Technology, followed by American Orthodontics, SIA, and Ortho Organizer (Table 2, Figure 4). Δa was negative (indicating a greener color) in Ortho Technology, and positive (indicating a redder color) in the remaining brands (Table 2, Figure 4). Finally, the highest Δb value was identified in SIA and Ortho Technology, showing a shift towards yellowness. ΔE was affected mainly by Δb and then by ΔL (Table 2).

Pairwise comparisons of ΔE values with the Bonferroni test revealed statistically significant differences between all brands ($P<0.05$), except between SIA and Ortho Technology ($P>0.05$; Table 3).

To understand the impact of quadrant on discoloration of ligatures, the ΔE was compared among different teeth and quadrants but no statistically significant difference was found ($P>0.05$). The upper left quadrant and tooth number 3 showed slightly higher ΔE when compared to other quadrants and teeth, but it was not statistically significant (Figure 5).

DISCUSSION

The results revealed that discoloration occurred in all four brands, and Ortho Technology and SIA had the lowest color stability. Additionally, it was found that discoloration was not affected by tooth type or quadrant. Also, no significant difference was found between the scoring by patients and orthodontists regarding discoloration. In the present study, clear and pearl elastomeric ligatures were used. It is necessary to consider that the initial color of ligatures affects their color change. To determine the effect of initial color of ligatures on their discoloration, Saliva et al. [16] evaluated four color groups, including blue, pearl, colorless, and white pearl.

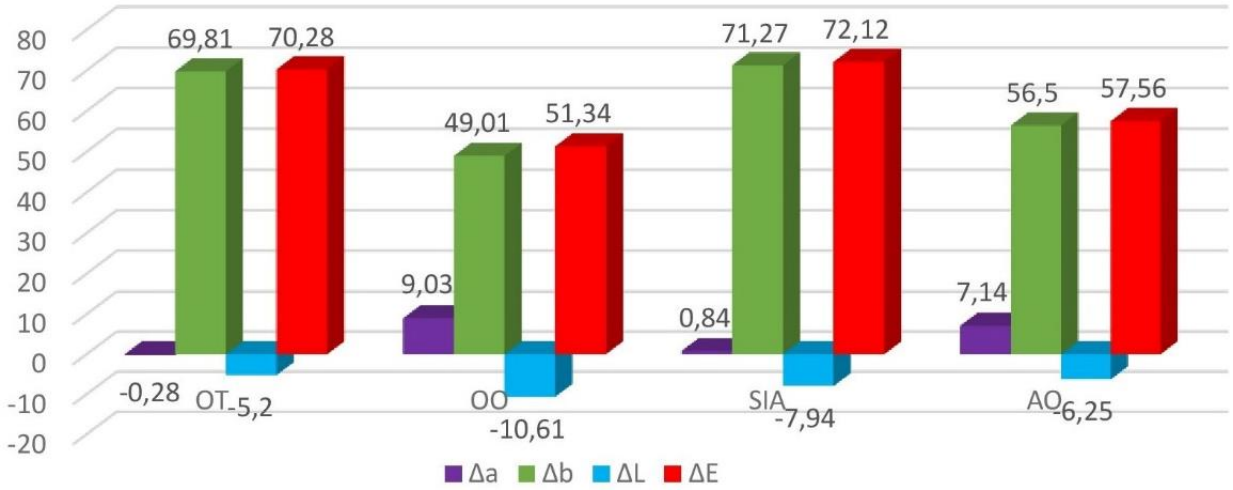

Fig 4. Mean Δa, Δb, ΔL, and ΔE of elastomeric ligatures from different brands; OT: Ortho Technology; OO: Ortho Organizers; AO: American Orthodontics

Table 2. Mean Δb, Δa, and ΔL for different brands of elastomeric ligatures

GROUP	ΔL			Δb			Δa		
	Mean ±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD	Min	Max
Ortho Technology	-5.2±4.1	-23.3	1.6	69.8±11.6	40.7	85	-0.2±4.2	-7.6	18
Ortho Organizers	-10.6±4.4	-26	-3	49.0±7.9	25.3	64	9.0±2.8	3.3	16.3
SIA	-7.9±4.7	-25.3	0	71.2±10.4	39	83	0.8±5.0	-7.3	18.6
American Orthodontics	-6.2±3.8	-18.6	0.6	56.5±9.4	35.3	71	7.1±2.8	1	15.6

SD: standard deviation; Min.: Minimum; Max.: Maximum

They showed that the color change differed among different groups, and the slightest color change was observed in the colorless group from the American Orthodontics brand [16]. The results showed the highest color stability in pearl American Orthodontics and Ortho Organizers. The current results were in agreement with the findings of Kawabata et al, [15] who showed that American Orthodontics elastomeric ligatures had the highest color stability. [15] Nakhaei et al. [9] demonstrated the possible relationship of initial color and color change of American Orthodontics and Ortho Technology brands. These findings do not support the results of a previous in vitro study reporting that the initial color of elastomeric ligatures did not influence their ΔE [18]. Additionally, a recent investigation demonstrated that the initial color of elastomeric ligatures affected their microbial adhesion, which can contribute to discoloration [19].

After 28 days of exposure to the oral environment, all brands exhibited a change in color stability. Regarding the ΔE value, the highest color change was due to increased yellowness in all ligatures, which was more prominent in SIA and Ortho Technology. This finding indicated that yellowness had a higher impact on ΔE; in fact, Δa had a smaller effect on ΔE than Δb and ΔL. This finding agrees with the results of Kadhum and Alhuwaizi [8] who assessed four brands of elastomeric ligatures after 4 weeks in the oral environment. They indicated that Δa had the lowest effect on ΔE. Additionally, they found that after the 1st and 2nd weeks, Δb had the greatest effect on ΔE, followed by ΔL at 4 weeks. Flores et al. [20] evaluated the effects of a bleaching toothpaste on color stability of elastomeric ligatures from various companies. They showed that toothpaste could not minimize the color change.

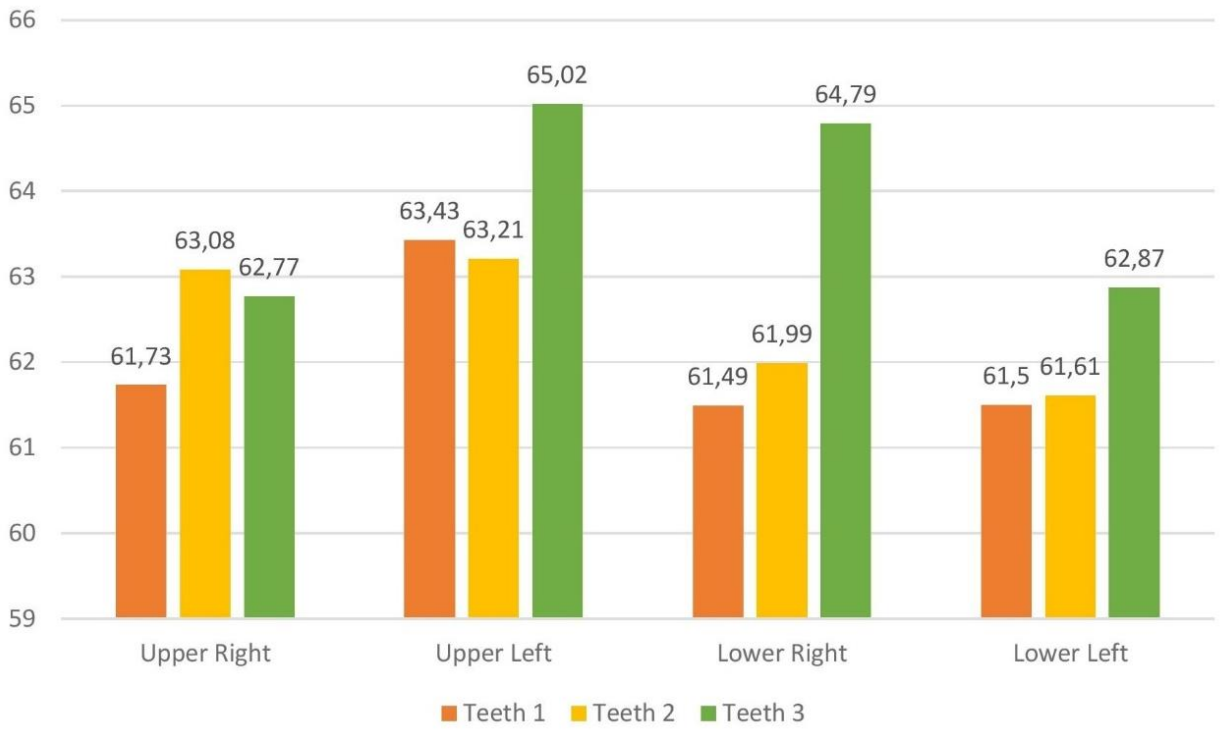

Fig 5: Mean ΔE based on tooth type and quadrant

Table 3. Median and P values at T0 and T1 based on the perception of orthodontists and patients

		Median				P
		Ortho Organizers;	SLA	Ortho Technology	American Orthodontics	
T0	Patients	3	2	1	3	<0.001
	Orthodontists	3	2	1	4	<0.001
T1	Patients	3	2	2	3	<0.001
	Orthodontists	3	2	2	3	<0.001

Several factors contribute to discoloration of elastomeric ligatures. Among them, the influence of colored foods is more prominent. In this regard, Miranda et al. [21] analyzed the ligatures' color change after exposure to commonly consumed colored drinks to better understand the impact of food color. They indicated that American Orthodontics and Ortho Organizers experienced the lowest color change compared with other brands, which was in line with the present results. Additionally, Silva et al. [18] demonstrated that black tea, wine, and coffee caused significant discoloration of elastomeric ligatures. On the other side, it was found that bacterial endotoxins had affinity for elastomeric ligatures, which can further contribute to their discoloration [22]. In the same study, the color stability of clear ligatures was compared following immersion in various solutions. They indicated that the most significant color change was observed in clear ligatures from American Orthodontics, clear ligatures from GC, clear ligatures from Ormco, and tooth-colored ligatures from Ormco. Nonetheless, it should be noted that due to differences in diet and oral hygiene of patients, discoloration of ligatures may vary from patient to patient [15]. Further investigations are required to assess the correlation between the type of diet and ligatures' color change.

CONCLUSION

The present study provided additional evidence about the color stability of elastomeric ligatures. After 28 days, discoloration was observed in all elastomeric ligature brands. Ortho Technology and SIA showed the highest color change and

lowest visibility. However, because of their transparency, they were more popular among patients. It was impossible to assess the impact of initial ligatures' color on severity of discoloration.

ACKNOWLEDGMENTS

None declared.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests.

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