Assessment of the Color Stability of Clear Elastomeric Ligatures (*In Vivo* Study)

Shams Kadhum, B.D.S [a]
Akram Faisal Alhuwaizi, B.D.S., M.Sc., Ph.D. [b]

ABSTRACT

Background: The desire for an attractive appearing fixed orthodontic appliance fueled the use of ceramic brackets and clear accessories. Elastics are one of the most versatile materials available to orthodontists so studying their effect on the esthetic appearance is important. This an in vivo study, conducted to evaluate the effect of exposing stretched clear elastomeric ligatures to the oral environment from four different companies (OrthoTechnology, Morelli, Ortho Organizer, and Ormco).

Materials and Methods: A total of 240 elastomeric modules were examined, 60 modules from each brand. Each of the 60 patients enrolled in the study, received 4 elastomeric modules on the 4 lower incisors, one from each brand. The specimens were placed on the teeth for 1, 2 and 4 weeks. After removal each module was kept in a sealed plastic bag and prepared for imaging and color measurement. Color measurements were made before and after use of the specimens. Images were taken by a cellular attachable microscope connected to a mobile phone with special J-cam program and the color change was calculated according to CIE Labcolor spaces system by the Adobe Photoshop program. The resulting data were statistically analyzed using ANOVA, LSD and Chi square tests.

Results: The results showed that, all the elastomeric ligatures discolored after use. The discoloration increased with an increased incubation period in the mouth reaching the peak at 4 weeks interval and the yellowness index was the mostly effected color component. Elastomeric ligatures from Morelli brand were the most prone to discoloration, while Ortho Organizers and Ormco ligatures were the least prone to discoloration with the presence of large individual variation.

Conclusion: It is necessary to alert the patient about the color changes that the clear ligatures experienced and the staining effect of certain foods. The orthodontist should select brands that are more resistant to color changes.

Keywords: Elastomer, discoloration, ligature. **(J Bagh Coll Dentistry 2017; 29(3):128-134)**

INTRODUCTION

The invisibility of orthodontic appliance is a major demand of orthodontic treatment, especially among adult. Ceramic brackets and clear elastomeric ligatures have advantages of being transparent. While the ceramic bracket are stain resistant, the elastomeric ligatures do stain by certain foods.

Discoloration of elastomeric ligatures is a major problem to both patient and orthodontist since this has a negative social impact on the esthetic appearance, affect the frequency of dental visits and the financial cost. Therefore, concern has been raised regarding the quality of material whether one brand is superior to another in efficiency and cost effectivness.

Many studies have evaluated the effect of the oral cavity on the elastic properties of elastomeric ligatures such as friction [1], force decay [2] and the caries-preventive effect of fluoride-releasing elastomers [3,4]. However, researchers have shown little concern about the behavior of orthodontic elastic materials after exposure to the oral environment, especially the extent to which these changes interfere with the esthetic.

Orthodontic elastomeric ligatures are made of polyurethane and can be produced by injection or matrix molding method [5,6]. Polyurethane is not an inert material decomposed in exposure to water, enzyme, heat and humidity for prolonged periods [7]. This causes staining of the ligatures when exposed to certain foods [8]. Turmeric, coffee and tea reported to have rapid staining potential unlike tomato ketchup and chocolate, which had gradual staining properties [9,10]**.** Also, the potential presence of crack of elastomeric ties resulting from its fixation to the brackets could have yielded a higher staining result [11].

Discoloration can be evaluated with different instruments and techniques such as camera or spectrophotometer [12,13]. These tools don't provide an insight into the perception of human to the discoloration and visual esthetic properties of elastic modules. In assessing the chromatic differences, the commission International de ´Eclairage (CIE L, a, b) system was chosen for the present study. This system widely used to calculate the total color change $\sum\Delta E$ [14,15].

This in vivo study was conducted to evaluate the effect of exposing stretched clear elastomeric ligatures to the oral environment from four different companies namely; OrthoTechnology, Morelli, Ortho Organizer, and Ormco.

[a] Master Student. Department of Orthodontics, College of Dentistry, University of Baghdad.
[b] Professor. Department of Orthodontics, College of Dentistry, University of Baghdad.

MATERIALS AND METHODS

The Sample

The sample includes sixty patients with well aligned lower incisors. The subjects participated in this study were advised to keep pigmented food and beverages as minimum as possible to prevent staining of the clear elastomeric modules. Oral hygiene instructions were also given.

Materials

Four types of elastomeric ligatures, transparent in color were selected from the following companies (Ortho Technology, Lot 404-002, Florida, USA, Ormco, Lot 6401264, Scafati, Italy, Ortho Organizer, Lot 400-223, Langenhagen, Germany, Morelli, Lot 60.06.100, Sorocaba, Brazil).

Method of Preparing the Specimen

Each patient who passed the alignment stage was informed about the aims of the study and given a consent form to read and sign. Then each bracket of the four mandibular incisors was engaged with an elastomeric module from one of the four brands.

The order of the four brands of the ligature modules on the lower four incisors was random for each patient and was carefully noted on the patient's case sheet. The sixty patients were divided into 3 groups (20 each) according to the time between insertion and removal of the modules:

Group 1: for 1 week.
Group 2: for 2 weeks.
Group 3: for 4 weeks

Measurement of the color changes

After 1, 2 and 4 weeks, each module was removed and stored in a sealed plastic bag with clear identification.

An X-ray viewer was used with a black opaque paper with a central hole of 2.5mm radius was used to minimize the light reflection and enhance image quality. Each elastomer was placed in the center of the hole. The cellular attachable microscope was connected to a mobile phone running Android software and J-cam application. The microscope was placed immediately above the ligature, so its border was in intimate contact with the X-ray viewer. A snapshot is taken to each module under X2 and stored in the phone's memory.

The photos were then transferred to the laptop computer and opened in commercial software (Adobe Photoshop 2015, version 7.0 Model:5; Adobe Systems ME., San Jose, California, USA). Four areas, average 5×5 pixels [8] were randomly selected from up, down, right and left sides using the 'eyedropper' tool for each elastic ring.

The color changes were calculated using the CIE Lab System proven by the Commission Internationale de ´Eclairage. In the CIE Lab uniform color space, the coordinates were:

L-the lightness coordinates.

a- the red/green coordinate with +a representing red and -a representing green.

b-the yellow/blue coordinate with +b representing yellow and -b representing blue.

The total color difference ΔE for each specimen was calculated by the following equation [15]:

$$\Delta E^* = \left(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}\right)^{\frac{1}{2}}$$

Color measurements were made before and after immersion of the elastomer specimens.

Statistical analyses

Data were collected and analyzed by using statistical package of social science program (SPSS, Chicago, Illinois, USA). In this study the following statistics were used:

A. Descriptive statistics: Including mean, standard deviation, frequency and statistical tables.
B. Inferential statistics:
1. One-way analysis of variance (ANOVA) test.
2. Least significant difference (LSD) test when ANOVA test was statistically significant.
3. Chi-square test.

RESULTS

The means, standard deviations, minimum and maximum values of the color change are presented in table 1. It was obvious that OT had the highest mean value of color changes at the 1st and the 2nd week followed by Mo. For the 4th week Mo had the highest mean value of color change.

All the color components (ΔL, Δa and Δb) differed for different brands at different time intervals.

Table 1: Descriptive data of the ∑ΔE change in color of the elastomers.

		Mean	SD	Min.	Max.
1 week	Mo	9.129	5.044	2.32	22.36
	OO	6.927	5.036	1.03	21.42
	Or	8.089	6.037	1.44	27.18
	OT	9.269	5.895	2.89	26.02
2 weeks	Mo	7.092	4.702	1.64	21.96
	OO	6.228	3.991	1.09	18.06
	Or	5.666	5.276	1.15	20.98
	OT	7.358	4.843	2.29	24.71
4 weeks	Mo	20.810	15.079	2.93	60.15
	OO	19.351	17.494	2.17	73.55
	Or	15.734	12.471	1.15	44.22
	OT	12.553	10.863	1.50	46.02

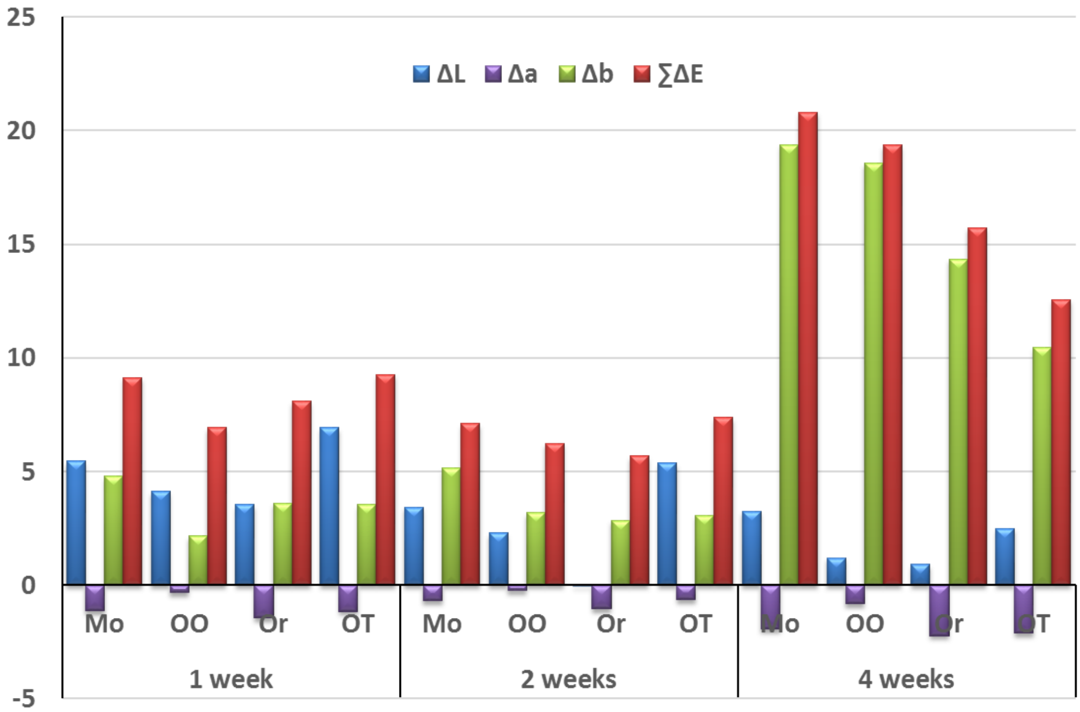

Figure 1: Mean ΔL, Δa, Δb and ∑ΔE change in color of the elastomers.

The highest mean value of ΔL for the 1st and 2nd week, was OT followed by Or. Mo showed the highest mean value of ΔL at the 4th week, followed by Or. While, the highest mean value of Δa was for Or followed by OO at the 1st, 2nd and 4th weeks. Lastly, Δb showed the highest mean value for Mo in the 1st, 2nd and the 4th weeks (Fig.1).

It is clear to see that ∑ΔE values were mostly affected by ΔL and Δb values in the 1st and the 2nd week, while the effect of ΔL greatly diminished in the 4th week leaving Δb as the key influencer on ∑ΔE values. However, the values of Δa were much lower than ΔL and Δb values and hence much less influential on ∑ΔE values (Table 1).

ANOVA test showed statistically significant differences of ∑ΔE for Mo, OO and Or elastomeric ligatures, while OT showed a non-significant difference. However, the ANOVA test showed significant differences of Δb for all four brands of elastomeric ligatures. When these differences were tested by LSD test both ∑ΔE and Δb showed a non-significant difference between 1 and 2 weeks interval, however the differences between 1 and 4 weeks and between 2 and 4 weeks intervals were statistically significant (Table 2 and Table 3).

On the other hand, differences between Δa were statistically non-significant for all four brands of elastomeric ligatures as examined by ANOVA test (Table 2).

Lastly, ΔL changed significantly with time for OO, Or and OT elastomers, while Mo showed a non-significant difference. However, LSD test showed statistically significant differences of OO at 1 and 4 weeks interval, While Or elastomers significant at 1 and 2 weeks interval (Table 2).

At 1 and 4 weeks and 2 and 4 weeks intervals OT elastomers have significant differences. For all time intervals ANOVA test showed non-significant differences for all the color components, except for ΔL at 1 and 2 weeks. However, LSD test of ΔL showed significant differences for 1 and 2 weekss intervals between OT with OO and Or elastomers (Table 3).

When comparing the color change of different brands of elastomers, Mo showed a significant difference from Or elastomers at 2 weeks only (Table 4 and 5).

The frequency of discoloration

The data analysis has clearly shown that there is a great individual variation in the discoloration of the clear elastomeric ligatures of all brands at different time intervals. This was seen in the high standard deviation values. Therefore, the discoloration value for the different elastomers was compared separately for each patient. Of the four elastomers, the one which showed the least discoloration took a score of 1 and the one with the most discolorations scored 4. Cross tabulation of these scores is shown in table 6.

In the 1 and 2 weeks groups, OT and Mo elastomers showed the most discolored ligatures with the former being marginally more discolored. While, OO and Or elastomers being the least discolored. However, these differences were statistically non-significant when tested by Chi square test.

Remarkably, in the 4 weeks groups, Mo elastomers showed the highest discoloration in 16 patients (80%) while OT elastomers showed the least discoloration. These differences were statistically highly significant when tested by Chi square test.

Table 2: ANOVA test between the color change of elastomers aged for different time intervals.

		F	p	Sig.
Mo	ΔL	2.680	0.077	NS
	Δa	1.746	0.184	NS
	Δb	13.206	0.000	p<0.001
	∑ΔE	11.959	0.000	p<0.001
OO	ΔL	4.534	0.015	p<0.05
	Δa	0.530	0.591	NS
	Δb	13.001	0.000	p<0.001
	∑ΔE	9.417	0.000	p<0.001
Or	ΔL	3.762	0.029	p<0.05
	Δa	2.001	0.145	NS
	Δb	9.675	0.000	p<0.001
	∑ΔE	7.537	0.001	p<0.01
OT	ΔL	7.206	0.002	p<0.01
	Δa	3.009	0.057	NS
	Δb	4.986	0.010	p<0.05
	∑ΔE	2.351	0.104	NS

Table 3: LSD test between the color change of elastomers aged for different timeintervals.

		1 week – 2 weeks		2 weeks – 4 weeks		1 week – 4 weeks	
		p	Sig.	p	Sig.	p	Sig.
Mo	Δb	0.911	NS	0.000	p<0.001	0.000	p<0.001
	∑ΔE	0.504	NS	0.000	p<0.001	0.000	p<0.001
OO	ΔL	0.068	NS	0.267	NS	0.004	p<0.01
	Δb	0.776	NS	0.000	p<0.001	0.000	p<0.001
	∑ΔE	0.838	NS	0.000	p<0.001	0.001	p<0.001
Or	ΔL	0.011	p<0.05	0.491	NS	0.056	NS
	Δb	0.795	NS	0.000	p<0.001	0.001	p<0.001
	∑ΔE	0.374	NS	0.000	p<0.001	0.007	p<0.01
OT	ΔL	0.194	NS	0.018	p<0.05	0.000	p<0.001
	Δb	0.864	NS	0.007	p<0.01	0.011	p<0.05

Table 4: ANOVA test between the color change of different brands of elastomers.

Measurement	Time	F	p	Sig.
ΔL	1 week	3.720	0.015	p<0.05
	2 weeks	7.096	0.000	p<-0.001
	4 weeks	1.810	0.152	NS
Δa	1 week	1.857	0.144	NS
	2 weeks	1.156	0.332	NS
	4 weeks	1.116	0.348	NS
Δb	1 week	0.494	0.688	NS
	2 weeks	0.889	0.451	NS
	4 weeks	1.559	0.206	NS
∑ΔE	1 week	0.775	0.512	NS
	4 weeks	0.545	0.653	NS
	4 weeks	1.367	0.259	NS

Table 5: LSD test between the color change of different brands of elastomers.

Group 1	Group 2	ΔL 1 week	ΔL 2 weeks

		p	Sig.	p	Sig.
Mo	**OO**	0.225	NS	0.346	NS
	Or	0.085	NS	0.005	p<0.01
	OT	0.193	NS	0.108	NS
OO	**Or**	0.604	NS	0.057	NS
	OT	0.013	p<0.05	0.012	p<0.05
Or	**OT**	0.003	p<0.01	0.000	p<0.001

Table 6: Frequency distribution of the elastics according to their rank in each patient according to their color.

Rank	1 week				2 weeks				4 weeks			
	Mo	**OO**	**Or**	**OT**	**Mo**	**OO**	**Or**	**OT**	**Mo**	**OO**	**Or**	**OT**
1	5	9	5	1	3	4	11	2	2	3	5	10
2	1	4	7	8	6	5	4	5	1	7	6	6
3	8	4	4	4	6	7	1	6	1	8	7	4
4	6	3	4	**7**	5	4	4	7	16	2	2	0
Cumulative score	55	41	47	57	53	51	38	58	71	49	46	34
Chi Square Test	X^2= 16.8 D. f. = 9 p= 0.052 (NS)				X^2= 16.0 D. f. = 9 p= 0.067 (NS)				X^2= 50.8 D. f. = 9 p= 0.000 (p<0.001)			

DISCUSSION

The majority of the studies on elastromeric ligatures' color stability have been conducted in vitro using one dying solution at a time. Some researches focused on the high staining potential of coffee and tea [6,16-18], while others explain the rapid staining effect of turmeric on the elastomeric materials and esthetic brackets [19,10].

These experimental studies could determine the types of food that contribute more significantly to the esthetic degradation of elastomeric ligatures; however, in this study an in vivo approach was selected because it can yield results that are closer to reality because the oral environment includes several factors that may affect the color uptake of elastomeric ligatures:

1- Several types of dying food substances (e.g. coffee, tea and beverages).

2- Several types of dying non-food substances (e.g. lipstick,drugs,toothpaste,mouth wash and smoking effect).

3- Temperature fluctuation [11].

4- Friction with tooth brush, food, orthodontic appliance, and oral tissues.

5- Chemical and bacteriological effect of oral hygiene measures.

6- Stretching force, staining is more likely to occur under stretching because of increased pigment absorption [20]. The potential presence of cracks in elastic ties resulting from its fixation to the brackets could yield a higher discoloration result [11].

7- The effect of the salivary enzymes and the pH, which affect the calcification rate of the biofilm on the surface of the elastomers in addition to the salivary washing effect [21].

8- Oral microbiota: after a few weeks of intra-oral exposure, elastomeric surfaces were found to be covered by well mineralized proteinaceous films.

The vastly altered composition and surface structure of the tested modules is strongly indicative of the severity of the changes happened [21].

The CIE L ab color spaces system was used for the assessment of the color changes. This system was commonly used for the determination of small color differences [22]. The advantage of this system for color measurement is that it more strictly represents human sensitivity to colors [23].

When comparing ΔL, Δa and Δb values the results found that the ΔL of all companies decreased after 1, 2 and 4 weeks. This may be because of the increased opacity of the elastomeric ligatures after exposure to the oral environment. These findings agree with those of Olivera et al. [20] who tested in vitro clear elastomeric ligatures from Mo and 3M and also showed a decrease in luminosity after soaking in red wine for 1 to 4 weeks in spite of tooth brushing. Δa showed the least readings of the three color components and hence had a minimal effect on ∑ΔE values which is in agreement with the findings of Olivera et al. [20].

The yellow index (Δb) increased gradually between 1 and 2 weeks, reaching the peak at the 4th week where it became the main influence of ∑ΔE values. This finding agrees with those of Ardeshna and Vaidyanathan [6] who tested in vitro the color stability of clear and colored elastomeric ligatures from American Orthodontics, Or, TP Orthodontic and 3M following the exposure to tea, coffee, cola and spices.

For all the elastomeric ligature brands the highest readings of the color changes (ΔE and Δb) were shown at the 4th week. This is because the discoloration of orthodontic polyurethane is a time dependent process which result from water absorption first, followed by chemical degradation of the elastomers [24]. This agrees with the findings of several in vitro studies, like Kim and Lee [8] who studied the effect of distel water, ethanol and methylene blue on ΔE of orthodontic elastomeric modules for 1 to 5 days and agrees with Oliveira et al. [20] who concluded that ΔE and Δb increased over time from 1 week to 4 weeks.

All the test specimens exhibited significant color changes irrespective of the commercial brand. The difference between the various brands was statistically non-significant and no clear pattern was found regarding the susceptibility of a particular brand of elastomeric ligatures to discoloration.

These differences between companies might be because of several factors like the chemical composition, porosity and manufacturing details. The manufacturing process of the modules is usually associated with the incorporation of microfissures that can facilitate the higher discoloration potential of certain types of modules. Their composition directly influences their configuration and their ability to resist deterioration caused by external agents [6]. This may partially explain the presence of pigmentation in all experimental groups.

Elastomeric ligatures from Mo company were the most discolored brand. This was consistent with the findings of studies reported by Da Silva et al. [22] who tested in vivo the color stability of Mo, Uniden, AO and TP ligatures after 4 weeks. Also, in agreement with Closs et al. [11] who tested in vitro the color stability of elastomeric ligatures from Mo, TP Orthodontics, RMO and GAC following the exposure to coffee, black tea, cola and red wine for 4 weeks.

Elastomeric ligatures from OO and Or modules showed the least mean staining. This agrees with Fernandes et al. [16] for OO ligature, who tested in vitro the effect of coffee and black tea on the color stability of OO, Unitek, Mo, OT, TP, GAC American Orthodontics ligatures for 1 week. These findings also agree with Talic and Almudhi [18] for Ormco ligatures, who tested in vitro the color stability of Unitek, Ormco, and Dentaurum ligatures after immersion in coffee, black tea, chocolate, energy drink, ketchup, and coca-cola for 3 days. Wide variation in the discoloration of elastomeric ligatures of the same brand was detected in different patients and may be due to differences in diet and oral hygiene habit. Also, the specific bioflora and its biproducts may contribute to the alteration of these polymeric materials [25].

There are several limitations of this study including the high individual variations and hence the results may not apply to every patient because of differences in diet and oral hygiene habits, color changes of the elastomers are very difficult to assess because they do not have a flat surface and have a hole in the middle, lastly the interpretation of the human eye may differ from the results of the L, a and b test.

Clinical Consideration

1. The orthodontist should select the most appropriate brand of elastomeric modules that have good staining resistance.
2. The orthodontic patient should be advised to minimize the consumption of food and beverages with a high pigment content and should maintain good oral hygiene.

In conclusion:

1. The color of clear elastomeric ligatures of all commercial brands changed after exposure to the oral environment.
2. Color changes were mostly affected by Δb (yellowness) of elastomeric ligatures.
3. The amount of discoloration increased gradually over time, reaching the peak at the 4th week.
4. The brand that underwent the greatest color change was Mo ligatures, while elastomeric ligatures from OO and Or were best preserved their color throughout the study.
5. Wide individual variation in the discoloration of elastomeric ligatures of the same brand was observed.

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الخلاصة

أصبح المظهر الجذاب لجهاز تقويم الأسنان الثابت أثناء المعالجة التقويمية أمر بالغ الأهمية، مما أدى الى استخدام حاصرات السيراميك والاكسسوارات التجميلية الشفافة . الاربطة المطاطية التقويمية هي واحدة من المواد الأكثر إستخداما في تقويم الأسنان لذلك من المهم دراسة تأثيرها على المظهر الجمالي لتقويم الاسنان الثابت. أجريت هذه الدراسة التطبيقية لتقييم تأثير البيئة الفموية على الاستقرار اللوني للاربطة المرنة التقويمية الشفافة ولاربع شركات مختلفة .

ضمت العينة 240 رابطة تقويمية شفافة, 60 رابطة من كل شركة . كل من الستون مشتركاً في هذه الدراسة أستلم اربعة أربطة تقويمية على القواطع السفلية الاربعة, واحدة من كل شركة . تركت العينات في البيئة الفموية لفترات زمنية مختلفة وهي 1و 2 و 4 أسابيع . بعد رفع العينات كل رابطة وضعت في غلاف بلاستيكي مغلق وحضرت لعملية التصوير وقياس الدرجة اللونية. اجري قياس الدرجة اللونية قبل وبعد الاستعمال لكل رابطة. الصور اخذت بواسطة عدسة مجهرية متصلة بجهاز الهاتف المحمول والقياس اللوني أجري باستخدام برنامج التحليل الصوري . تم تحليل البيانات الناتجة احصائياً بأستخدام إختبار تحليل التباين(ANOVA) وإختبار الفرق المعنوي (LSD) وإختبار مربع كاي (chi-square).

أظهرت النتائج إن كل الاربطة الشفافة يتغير لونها بعد الاستعمال وهذا التغير اللوني يزداد بمرور الوقت الى ان يصل الحد الاقصى في فترة الاربعة أسابيع مع وجود إختلاف كبير بين المشتركين. اظهرت الاربطة التقويمية من شركة Morelli أكبر عدم إستقرار لوني مقارنةً مع الشركات الاخرى , بينما الاربطة التقويمية من شركات Ormco و Ortho Organizer كانت الاكثر استقراراً لونياً بعد تعرضها للبيئة الفموية.