Discoloration of Stretched Clear Elastomeric Chains by Dietary Media (An in vitro study)

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ABSTRACT:

Background: With the increasing demand on esthetic orthodontic appliances, discoloration of clear elastomeric chains and modules remains an issue which concerns both orthodontics and patients. This in vitro study was conducted to evaluate the effect of exposing stretched clear elastomeric chains from six different companies (Ortho Technology, Ormco, Ortho Organizer, American Orthodontics, Opal and G&H companies) to three types of dietary media (tea, coffee and turmeric).

Materials and methods: A total of 960 lengths of six modules were cut from short type elastomeric chain; 160 pieces from each brand. The specimens were stretched 50%, placed on plastic boards, and incubated in water at 37°C for 1 day, 7 days, 14 days and 28 days. Once a day, the specimens were immersed for ten minutes in the testing dietary media, washed and then returned back to the water container. Color measurements were made before and after incubation of the specimens. Digital image were taken by an SLR digital camera and the color changes were calculated according to CIE L*a*b* color space system by Adobe Photoshop program. The resulting data were statistically analyzed using ANOVA and LSD tests.

Result: Elastomeric chains from AO, Opal and G&H companies were the most brands prone to discoloration. Ortho Organizers and Ortho Technology chains were the least prone to discoloration. Tea, coffee and turmeric solutions discolored elastomeric chains from all companies in a variable degree, however turmeric caused significantly more discoloration, followed by tea and least by coffee. The amount of discoloration caused by tea and coffee increases gradually to peak at 28 days, while most of the discoloration caused by turmeric was in the first day and reached a plateau in a week.

Conclusion: To decrease the discoloration of clear elastomeric chains the consumption of colored dietary media especially spices like turmeric are to be discouraged.

Key words: Clear elastomeric chains, discoloration, and dietary media. . **(J Bagh Coll Dentistry 2017; 29(2):97-103**

INTRODUCTION

Orthodontic patients, including a growing population of adults, not only want an improved smile, but they are also increasingly demanding better aesthetics during treatment. The development of appliances that combine both acceptable aesthetics for the patient and adequate technical performance for the clinician is the ultimate goal. This problem was partially solved by the introduction of aesthetic transparent brackets made of ceramic or composite [1]. However, while most of these brackets were resistant to stain, clear elastomeric chains used to retract teeth or to close spaces discolored if patients ate certain dietary media like coffee, tea and turmeric [2].

It is difficult to measure the colour of elastomerics using a spectrophotometer or a colorimeter because of their small size and curved geometry. Recent advances in digital cameras and imaging software encouraged their use in colour measurement for clinical dentistry. Moreover, a statistically significant correlation was found between a digital camera with an appropriate calibration protocol and a spectrophotometer [3].

There is some concern regarding the quality of elastomers and which company is superior to the others in efficacy or cost-effectiveness. Many studies have been carried out on the force decay of elastomeric chains [4,5]. However, the literature is very scares on studies on their color stability.

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MATERIALS AND METHODS

Six brands of clear orthodontic elastomeric chains were investigated (Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H). from each brand 160 pieces of 6 modules were cut. These had initial lengths of 16-19mm which when stretched 50% become 24-27.5mm long. This distance approximated the distance between the hook of the lateral bracket and the hook of the first molar tooth for en-masse retraction of the anterior teeth.

A total of 960 elastomeric chain specimens were tested, 240 for each dietary medium (distilled water, tea, coffee and turmeric) where distilled water served as a positive control.

Holding blocks were made by inserting 24 stainless steel pins perpendicularly into a plastic board making 12 pairs set at a distance of 50% more than the original length of the elastomeric chains (Fig. 1).

All the test specimens were placed on the holding blocks and incubated in water containers for 1, 7, 14 or 28 days at 37°C. Once each day, all the plastic holding blocks with their elastomeric

specimens were removed from water containers and immersed for ten minutes in the testing dietary media containers. After that, the holding blocks were removed from the dietary media containers and rinsed with copious amount of water to wash out any remnants of the dietary solutions and returned back and incubated in the water containers until the next day [6].

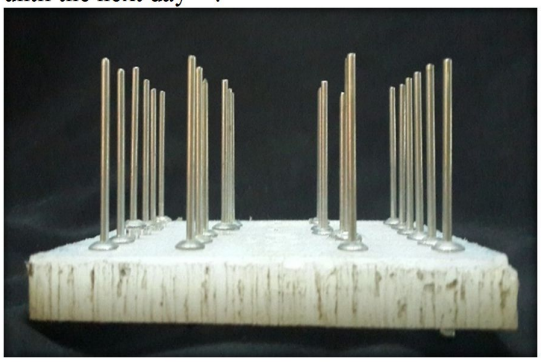

Figure 1: Plastic holding block.

Color measurements were made before and after immersion. A commercial SLR camera, Nikon D40 (Nikon Corp., Japan) with Tamron SP AF 18-55mm with 1:1 Macro lens (Saitama, Japan) were used. The digital camera was set to manual mode, which allowed total control of the shutter speed and aperture size. The shutter speed was set at 1/5 seconds with an aperture of F32, and the film sensitivity was set at International Organization for Standardization 200 sensitivity mode [7].

Digital images were taken in a darkroom with a ring fluorescent tube (OPPLE/ 40W, 6500K) as a light source. The fluorescent tube was perpendicularly fixed at a distance of 45cm from the platform where the elastomeric chains were placed. A standard grey card (DGK color tools) was used because neutral light grey was considered to be the ideal background for shade matching which had 17.68 % reflectance [7].

The digital image files were opened in Adobe Photoshop program (version 7.0; Adobe Systems Inc., San Jose, California, USA). Four areas (average 5 × 5 pixels) were randomly selected using the 'eyedropper' tool. The CIE *L**, *a**, and *b** values of each area were obtained using the 'Lab sliders' in the software. *L** is in the range of 0-100 and *a** and *b** in the range of -120 to 120. The *L**, *a**, and *b** values were calculated by averaging the four areas of each specimen. The three-dimensional CIE Lab color order system provided a useful standardization technique for color difference assessments. The system included three color co-ordinates. CIE *L** corresponded to the value (degree of lightness) in the Munsell system, and *a** and *b** co-ordinates designate the positions on the red/green and yellow/blue axes, respectively (+*a*= red, -*a*= green; +*b*= yellow, -*b*= blue). Color difference $\Delta E^* = \frac{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}{2}$ [8].

Statistical analysis

Data was collected and analyzed by using statistical package of social science program (SPSS, Chicago, Illinois, USA). Mean and standard deviation (SD) values were computed.

One-way analysis of variance (ANOVA) and least significant difference (LSD) tests were used to test the differences between brands and the effect of different dietary media.

P values of less than 0.05 were regarded as statistically significant.

RESULTS

Color changes (ΔE* ab) after immersion in the dietary media are displayed in table 1.

Difference between brands:

The difference of ΔE*values of elastomeric chains between different companies was minimal for the specimens immersed in water but was more evident for those immersed in tea, coffee and turmeric solutions (Fig. 2).

All the readings were comparable for all brands immersed in water. However, at 14 days ANOVA test showed a significant difference and LSD test showed that AO chains had a significant less ΔE*values than Ormco, Ortho Organizers and Opal chains (Table 2).

The highest color change caused by tea was for Opal (ΔE*=40.6), followed by AO (ΔE*=39.4), G&H (ΔE*=39.1), Ormco (ΔE*=38.9), Ortho Technology (ΔE*=35.1) and least was for Ortho Organizers (ΔE*=30.9). However, at 7, 14 and 28 days ANOVA test showed significant differences and LSD test showed significant differences between all brands (Table 2).

The highest color change caused by coffee was for Ormco (ΔE*=27.2), followed by G&H (ΔE*=26.3), Ortho Technology (ΔE*=24.8), Opal (ΔE*=23.8), AO (ΔE*=23.5), and least was for Ortho Organizers (ΔE*=22.2). However, at 1, 7 and 14 days ANOVA test showed significant differences and LSD test showed significant differences between all brands (Table 2).

The highest color change for the turmeric solution was for AO (ΔE*=57.5), followed by G&H (ΔE*=56.4), Opal (ΔE*=55.9), Ortho Organizers (ΔE*=53.4), Ormco (ΔE*=53.2), and least was for Ortho Technology (ΔE*=52.1). However, at all time intervals ANOVA test showed significant differences and LSD test showed significant differences between all brands (Table 2).

Difference between dietary media

For all brands, chains immersed in turmeric showed highest color change peaking at 28 days followed by tea then coffee and lastly water which showed only minimal color change (Fig. 3).

For all brands, ANOVA test showed significant differences for all media and all time intervals (Table 3).

LSD test for the specimens immersed in water showed significant differences from those immersed in tea or coffee for 7 to 28 days but not for 1-day. But for those immersed in turmeric solution the difference was significant from day 1 to 28 days.

LSD test for the specimens immersed in tea showed significant differences from those immersed in coffee for all brands and at all time intervals except at 1-day.

LSD test for the specimens immersed in turmeric solution showed significant differences from those immersed in tea or coffee for all brands and at all time intervals.

DISCUSSION

The color change values were recorded for test periods of 1, 7, 14 and 28 days in order to measure the relative changes occurring throughout the whole time period between visits.

A digital camera was used to assess the amount of color change because of its reliability and accuracy. Jarad et al. [3] used a 5-megapixel camera and found a highly significant correlation between a spectrophotometer and digital camera for all CIE L*a*and b* coordinates [9].

The CIE L*a* and b* color space was used for assessment of color changes. This system was commonly used for assessment of small color differences [10].

The discoloring effect of tea and coffee on elastomeric modules had been extensively researched, but turmeric was added to this investigation because of its widespread use in cooking. Recent researches had evaluated the discoloration caused by turmeric on esthetic brackets and elastomeric modules [11-14].

Difference between brands

From the result of this study, no clear pattern was found regarding the susceptibility of a particular brand of elastomeric chain to discoloration but these general points could be noted:

- Elastomeric chains from AO, Opal and G&H companies were the most discolored brands.
- Elastomeric chains from Ortho Organizers and Ortho Technology companies were the least discolored brands.

These differences might be because of several factors like the chemical composition and details of manufacturing and processing. The polyurethane used to make the elastomeric chains was made by several chemical reactions involving many compounds making products with different chemical compositions which affected the configuration of the chains of the elastomer and their ability to withstand deterioration from external agents and processing conditions [15]. The surface characteristics such as texture and porosity could be different [12].

To the authors' knowledge, there is no published report on the discoloration of elastomeric chains, therefore the comparison with other researches is not possible. However, previous researches on the discoloration of elastomeric modules also show a diversity in the intensity of discoloration caused by different media on the different brands of modules [4,12,14,16-18].

Difference between dietary media

In the present study, turmeric caused significantly more discoloration than tea and coffee. This agrees with previous studies [13] but disagrees with the findings of other studies [15] who found more discoloration of elastomeric modules caused by coffee than turmeric. The difference with Bhandari et al. [14] may be because of the different response of modules than chains and the variable company brands.

In the present study, tea caused significantly more discoloration than coffee. However, this disagrees with the findings of other studies carried out on elastomeric modules [12,14,16]. The difference may be because of the different chemical composition and manufacturing technique between elastomeric chains and modules.

Comparison between immersion times

Since all elastomeric brands tested underwent color change in all solutions over time, the storage period was taken to assess the degree of staining. It was seen that the storage time influenced the amount of color change of the elastomeric chains and this was agreement with Kim and Lee [8] and Bhandari et al. [14].

Exposure to water led to chemical degradation of polyester polyurethane. Substances leached from the polymer over time so that pigments and other compounds from dietary media could penetrate deep into elastomeric chains and cause discoloration [19,20].

Thus when the elastomeric chains were stretched, the stretching affected the color stability of elastomeric chains giving a significant difference between the readings of 1 day, 7 days, 14 days and 28 days after immersion in dietary media for all groups. This was in agreement with

Bhandari et al. [14] who found the amount of discoloration increased as the amount of immersion time increased.

The amount of discoloration caused by tea and coffee increased gradually to peak at 28 days. This agrees with the findings of Bhandari et al. [14] who found similar findings on elastomeric modules. This disagree with the findings of Lew [21] who found the amount of discoloration of elastomeric modules increased rapidly.

Most of the discoloration caused by turmeric was in the first day. After this period, there was trend towards saturation and reached a plateau at 7 days. This agrees with the findings of Bhandari et al. [14] who found the same outcome on elastomeric modules.

Limitations of the study:

Reader should be cautious when interpreting this data to the clinical condition. In vivo staining differs from that found in vitro because of the lack of bacteria, abrasion from occlusion, eating and brushing, salivary mucins and proteins and the dilution effect of saliva on the ingested dietary media.

Furthermore, the technique to assess color change needs further development because of the small surface area, clear color, and geometry of the elastomeric chains.

Clinical consideration:

1. The orthodontic patient should be advised to minimize the consumption of coloring foods like turmeric, tea and coffee to keep the esthetic appliance clear with minimum amount of discoloration to get benefit from choosing this type of appliance.
2. The orthodontist should use the clear elastomeric chains with the best color stability to minimize their discoloration to satisfy the patient.

CONCLUSION

1. Elastomeric chains from AO, Opal and G&H companies were the most brands prone to discoloration, while elastomeric chains from Ortho Organizers and Ortho Technology companies were the least ones.
2. Tea, coffee and turmeric solutions discolored elastomeric chains from all companies in a variable degree, however turmeric caused significantly more discoloration, followed by tea and least by coffee.

The amount of discoloration caused by tea and coffee increased gradually to peak at 28 days, while most of the discoloration caused by turmeric was in the first day and reaches a plateau at 7 days.

Table 1: Mean and standard deviation of the color changes (Δ E* ab) of all brands after immersion in the dietary media.

		1 day		7 days		14 days		28 days	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Water	Ortho Technology	6.578	4.376	6.849	3.375	6.649	1.706	6.887	1.943
	Ormco	5.492	2.044	4.815	1.714	4.884	3.129	6.202	1.867
	Ortho Organizers	8.508	4.215	6.932	2.8	6.202	2.531	7.717	3.851
	AO	8.011	2.689	8.414	3.86	8.873	3.246	7.856	3.99
	Opal	7.543	1.92	5.12	2.375	5.348	2.244	6.631	2.01
	G&H	8.189	5.076	7.679	3.204	7.375	3.82	7.437	4.021
Tea	Ortho Technology	9.515	3.534	17.097	2.126	24.933	3.027	35.088	4.685
	Ormco	7.539	2.467	17.097	1.074	29.462	1.578	38.9	2.028
	Ortho Organizers	9.781	3.271	14.963	2.699	27.625	4.182	30.876	4.657
	AO	9.944	2.773	20.932	4.844	25.627	5.73	39.428	4.458
	Opal	8.265	3.189	16.208	3.434	20.247	4.361	40.56	2.716
	G&H	11.616	5.637	23.61	3.744	29.782	5.3	39.081	6.05
Coffee	Ortho Technology	9.116	3.385	12.637	2.622	14.95	2.252	24.79	5.194
	Ormco	11.469	1.582	12.795	2.731	17.463	1.294	27.232	2.305
	Ortho Organizers	12.015	3.474	12.732	2.359	13.495	2.637	22.191	3.275
	AO	11.838	4.823	14.94	3.429	15.714	1.596	23.533	3.392
	Opal	14.575	1.753	13.481	2.825	14.312	1.681	23.831	3.487
	G&H	13.575	3.403	17.368	2.389	18.67	6.666	26.294	4.625
Turmeric	Ortho Technology	25.756	3.478	41.511	4.392	49.911	2.235	52.116	3.632
	Ormco	23.959	1.423	43.675	1.771	52.987	1.942	53.233	2.362
	Ortho Organizers	26.483	4.867	41.298	5.782	50.001	4.653	53.392	2.072
	AO	28.706	4.267	53.34	3.725	57.023	6.141	57.531	4.735
	Opal	23.928	2.088	44.607	2.186	51.33	5.449	55.898	2.415
	G&H	26.27	2.537	46.753	3.053	50.715	4.279	56.388	4.705

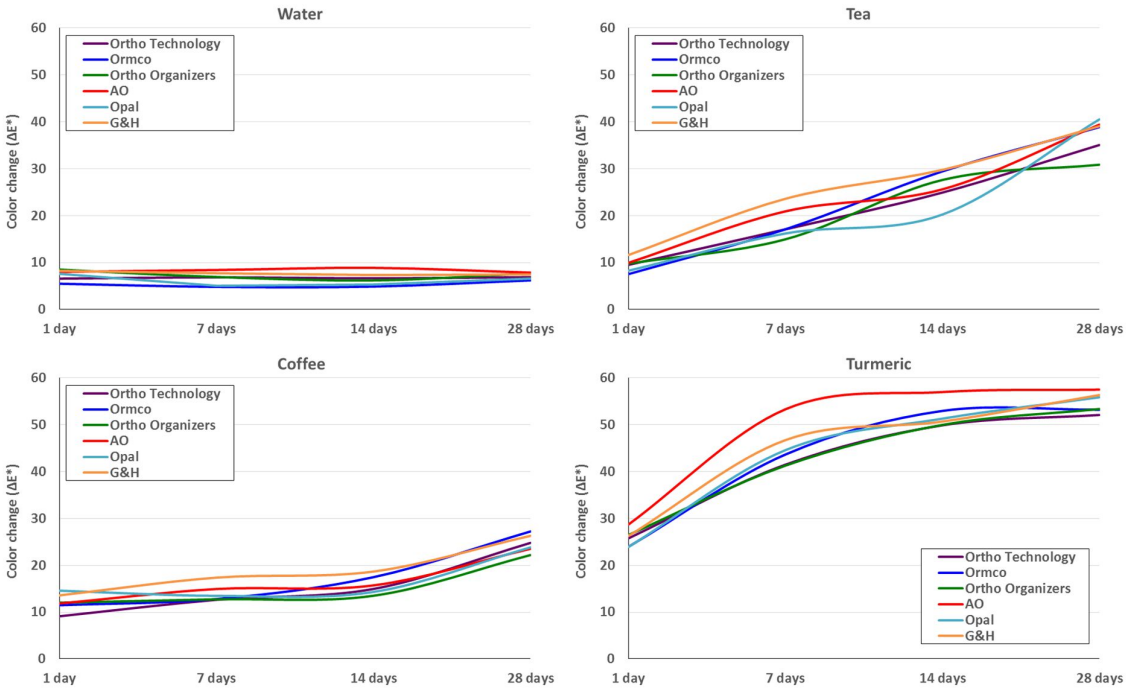

Figure 2: Color changes of elastomeric chains (Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H) after immersion in water, tea, coffee, and turmeric.

Table 2: Difference between the color changes of the elastomeric chains of different companies.

	Days	ANOVA	LSD Test														
			A B	A C	A D	A E	A F	B C	B D	B E	B F	C D	C E	C F	D E	D F	E F
Water	1	NS															
	7	NS															
	14	*	NS	NS	NS	NS	NS	NS	**	NS	NS	*	NS	NS	**	NS	NS
	28	NS															
Tea	1	NS															
	7	***	NS	NS	*	NS	***	NS	*	NS	***	***	NS	***	**	NS	***
	14	***	*	NS	NS	*	*	NS	NS	***	NS	NS	***	NS	**	*	***
	28	***	NS	*	*	**	*	***	NS	NS	NS	***	***	***	NS	NS	NS
Coffee	1	*	NS	NS	NS	***	**	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
	7	***	NS	NS	**	NS	***	NS	**	NS	**	**	NS	**	*	NS	**
	14	**	NS	NS	NS	NS	*	*	*	*	NS	NS	NS	**	NS	**	**
	28	NS															
Turmeric	1	*	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	**	NS	NS
	7	***	NS	NS	***	NS	**	NS	***	NS	NS	***	NS	**	***	***	NS
	14	**	NS	NS	**	NS	NS	NS	*	NS	NS	**	NS	NS	**	**	NS
	28	**	NS	NS	**	*	**	NS	**	NS	NS	*	NS	NS	NS	NS	NS

A. Ortho Technology, **B.** Ormco, **C.** Ortho Organizers, **D.** AO, **E.** Opal, **F.** G&H
NS= non-significant, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$

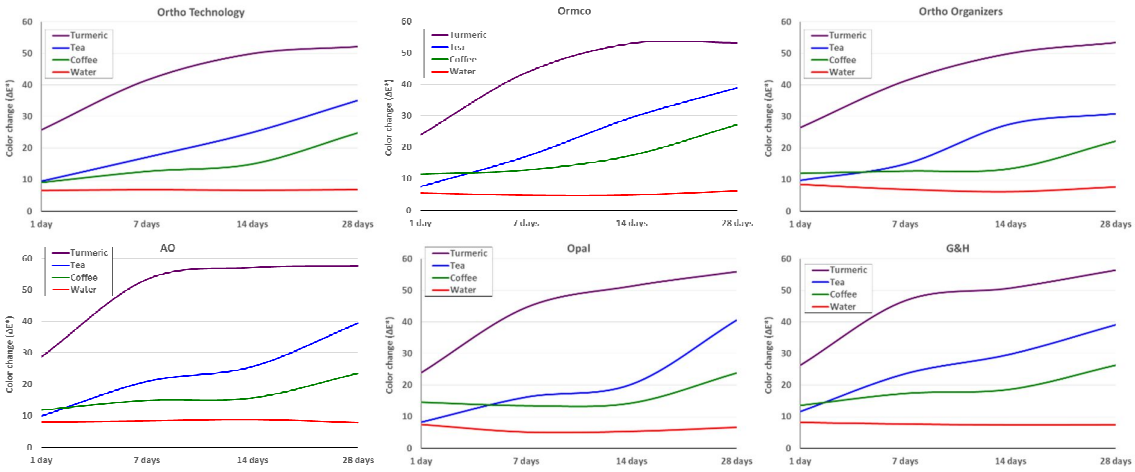

Figure 3: Mean color change of clear elastomeric chains from Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H companies after immersion in water, tea, coffee, and turmeric.

Table 3: Statistical difference between the color changes of the clear elastomeric chains immersed in different dietary media.

	Days	ANOVA	LSD Test					
			Water Tea	Water Coffee	Water Turmeric	Tea Coffee	Tea Turmeric	Coffee Turmeric
Ortho Technology	1	***	NS	NS	***	NS	***	***
	7	***	***	***	***	**	***	***
	14	***	***	***	***	***	***	***
	28	***	***	***	***	***	***	***
Ormco	1	***	*	***	***	***	***	***
	7	***	***	***	***	***	***	***
	14	***	***	***	***	***	***	***
	28	***	***	***	***	***	***	***
Ortho Organizers	1	***	NS	NS	***	NS	***	***
	7	***	***	**	***	NS	***	***
	14	***	***	***	***	***	***	***
	28	***	***	***	***	***	***	***
AO	1	***	NS	*	***	NS	***	***
	7	***	***	***	***	*	***	***
	14	***	***	*	***	***	***	***
	28	***	***	***	***	***	***	***
Opal	1	***	NS	***	***	***	***	***
	7	***	***	***	***	*	***	***
	14	***	***	***	***	**	***	***
	28	***	***	***	***	***	***	***
G&H	1	***	NS	**	***	NS	***	***
	7	***	***	***	***	***	***	***
	14	***	***	***	***	***	***	***
	28	***	***	***	***	***	***	***

NS= non-significant, * = p<0.05, ** = p<0.01, *** = p<0.001

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