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The effect of immersion different dietary media on the stretched clear elastic chains: An in vitro study

Athraa A Abass*

Department of Prosthodontic, College of Dentistry, University of Kerbala, Iraq

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ABSTRACT

Discoloration of clear elastic modules and chains remains an issue which concerns both orthodontics and patients when the increasing demand on esthetic orthodontic appliances. This study was conducted for evaluating the effect of exposing stretched clear elastic chains to three types of dietary media (turmeric, tea and coffee) from six different companies (Ortho Technology, Opal, Ortho Organizer, American Orthodontics, Ormco and G&H). The short type elastomeric chains were cutting about 960 of its lengths from six different companies; 160 pieces from each brand. The specimens were stretched 50%, placed on plastic boards, and incubating at (37°C) in water for (1) day, (7) days, (14) days and (28) days. Once a day, the cutting pieces were immersed in the dietary testing media for ten minutes, washed and then returned to the water container. Color measurements were made before and after incubation of the specimens. The data were statistically analysed using ANOVA and LSD tests. Elastic chains from Ormco, Ortho Organizers and Ortho Technology had the least prone to discoloration, and AO, Opal and G&H companies had the most brands 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. Most of the discoloration caused by turmeric is in the first day and reaches a plateau at a week, while the amount of discoloration caused by tea and coffee increases gradually to peak at (28) days. Consumption of certain dietary media such as tea, turmeric and coffee caused discoloration of clear elastomeric chains. The range of discoloration increased over time.

* Corresponding Author

Name: Athraa A. Abass
Phone: +9647718323089
Email: athraa.a@uokerbala.edu.iq

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INTRODUCTION

The needed for aesthetic orthodontic treatment had increased because the orthodontic treatment allowed a service for - many people. The brackets which made from ceramic had become famous for aesthetic reasons - The ceramic brackets were ligated by clear elastomeric chains had enhanced the aesthetic value of orthodontic appliances. The ceramic brackets resistant to the stain while the elastic chains discolored if patients consumed certain beverages or foods, such as coffee, turmeric and tea during appointments. This would lead to esthetic problems.

The spectrophotometer had an instrument popular used for measuring surface color due to its accuracy and reliability (Cal, 2004). There weresome limitations which couldn't use the spectrophotometer for analysing orthodontic elastic, for examples (geometric problems caused by the curvature of the elastomeric chains and the need for a relatively large measurement area) Commission

Internationale de l'Eclairage (CIE) Colorimetry., 2004). Modern advancing in computer science and photography resulted in the wide using of digital cameras for imaging the color. Elastic images resulted from a digital camera could be analysed by imaging software which enabling quantitative color parameters to collect from the whole or parts of such images. This parameter had simpler and costlier than a colorimeter and spectrophotometer (Jarad, 2005).

It found a significant correlation between the spectrophotometer and digital camera for all of the Commission International de l'Eclairage (Kim and Lee, 2009) L*, a*, and b* color coordinates (Commission Internationale de l'Eclairage (CIE) Colorimetry., 2004). Therefore, when combined with another calibration parameter, digital cameras used as a color measurement in the clinical dentistry (Lam *et al.,* 2002).

The remaining of elastomeric material in the oral cavity was of great matter. The studies on the behaviour of these materials in a wet environment had conducted in dietary media. However, it recognised that the discoloration of orthodontic elastic chains by specific dietary media could influence the aesthetic value of aesthetic orthodontic appliances such as ceramic brackets. In addition, the degradation of orthodontic elastic chains in the oral environment might be associated with discoloration. Discolouration of elastic chains might be reduced by determining the cause of discolouration and minimizing its potential effect as possible as (Paravina., 2002).

MATERIALS AND METHODS

The clear orthodontic elastic chains from six types were investigated (Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H). Twenty-four stainless steel pins were inserted perpendicularly into a plastic block making 12 pairs set at a distance of 50% more than the original length of the elastomeric chains (Paravina and Powers, 2004).

All the 960 tested specimens were placed on the holding blocks and incubated in water containers for (1; 7; 14 and 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 (Beattie and Monaghan., 2004).

After that, the holding blocks were removed from the dietary media containers and rinsed with a copious amount of water to wash out any remnants of the dietary solutions and returned and incubated in the water containers until the next day (Eliades *et al.,* 2004).

Color measurements were made before and after immersion for specified periods. A commercial SLR camera, Nikon D40 (Nikon Corp., Japan) with Tamron SP AF (18-55) mm with (1:1) Macro lens (Saitama, Japan) was used. The digital camera was setting manually to allow total control of aperture size and shutter speed. The shutter speed was setting to (1/5) seconds with an aperture of (F32), and the film sensitivity was setting at International Organization for Standardization (200) sensitivity mode (Lam *et al.,* 2002). Digital images were captured in a dark room with a fluorescent ring tube (OPPLE/ 40W, 6500K) as a light source. The fluorescent tube was placed in a perpendicular angle and fixed at about (45) cm of the plate form where the elastic chains were placing. The standard grey card (DGK color tools) was using because neutral light grey was considered to be the ideal background for matching shade which had 17.68 % reflection (Wee *et al.,* 2006).

The digital image files opened in the Adobe Photoshop program (version 7.0; Adobe Systems Inc., San Jose, California, USA). Four areas (average 5 × 5 pixels) selected randomly using the 'eyedropper' tool. The CIE *(L*)*; (*a**); and *(b**) values of each area of elastic chains obtained using the 'Lab sliders' in 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 calculated by averaging the four areas for each cutting elastic. The three-dimensional CIE Lab color order system provided standardisation technique for color change calibration. The system included three color coordinates. CIE (*L**) corresponded to the value (amount of lightness) in the Munsell system; (a*) and (*b**) co-ordinates designate the positions in (red/green) and (yellow/blue) axes, respectively (+*a*= red; -*a*= green; +*b*= yellow and -*b*= blue).

Color difference $\Delta E^* = \frac{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}{2}$ (Kim and Lee, 2009).

The statistical analysis

Data was collecting and analysing using a statistical package of social science program (SPSS, Chicago, Illinois, USA). Mean, and standard deviation (SD) values had computed.

One way the analysis of Variance (ANOVA) and Least Significant Difference (LSD) tests used to test the differences between brands and the effect of different dietary media.

(P) values of less than (0.05) regarded as insignificant statistically.

RESULTS

Color changes (ΔE*L a b) after immersion in the dietary media displayed on the table (1).

Table 1: Mean and standard deviation of the color changes (Δ E* ab) of all companies 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

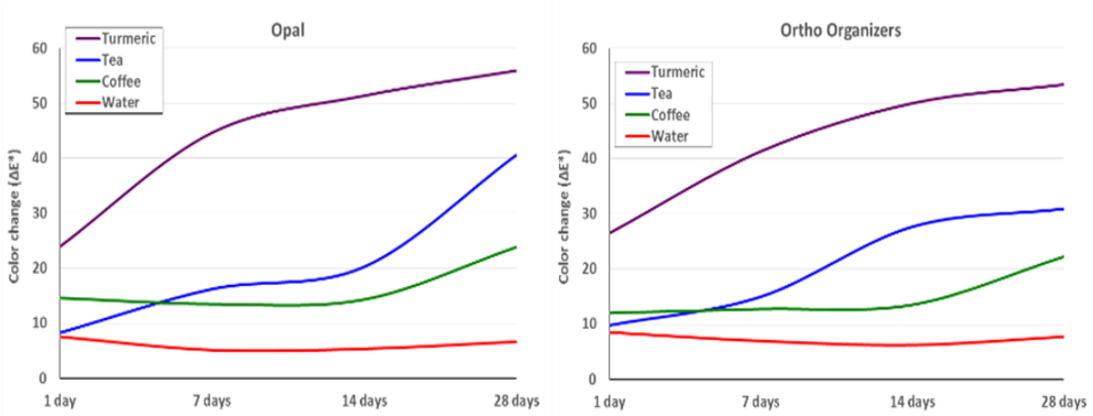

Figure 1: Color changes of elastomeric chains (Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H) after immersion in water, tea, coffee, and turmeric

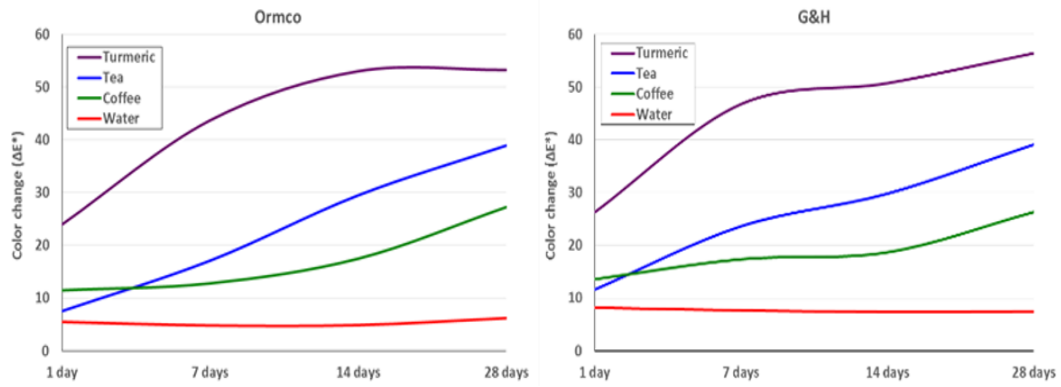

Figure 2: Mean color change of clear elastomeric chains from Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H companies after immersion in water, tea, coffee, and turmeric

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

			LSD Test							
		ANOVA	A	A	A	A	A	B	B	B
			B	C	D	E	F	C	D	E
Water	1	0.410								
	7	0.061								
	14	0.040	0.173	0.727	0.089	0.319	0.577	0.308	0.003	0.710
	28	0.817								
Tea	1	0.201								
	7	0.000	0.994	0.145	0.010	0.539	0.000	0.147	0.010	0.544
	14	0.000	0.021	0.161	0.707	0.017	0.014	0.344	0.051	0.000
	28	0.000	0.053	0.033	0.028	0.006	0.043	0.000	0.784	0.393
Coffee	1	0.011	0.112	0.052	0.068	0.000	0.003	0.712	0.806	0.037
	7	0.000	0.900	0.943	0.006	0.514	0.000	0.956	0.009	0.598
	14	0.006	0.108	0.348	0.566	0.679	0.019	0.013	0.031	0.045
	28	0.052								
Turmeric	1	0.022	0.230	0.636	0.054	0.223	0.739	0.097	0.002	0.984
	7	0.000	0.201	0.900	0.000	0.070	0.003	0.162	0.000	0.580
	14	0.003	0.118	0.959	0.001	0.464	0.926	0.130	0.040	0.398
	28	0.006	0.478	0.417	0.001	0.019	0.009	0.919	0.008	0.095

A. Ortho Technology, B. Ormco, C. Ortho Organizers, D. AO, E. Opal, F. G&H

Table 2: Difference between the color changes of the elastomeric chains of different companies (Contd…)

			LSD Test							
		ANOVA	B	C	C	C	D	D	E	B
			F	D	E	F	E	F	F	F
Water	1	0.410								
	7	0.061								
	14	0.040	0.057	0.042	0.515	0.365	0.008	0.247	0.123	0.057
	28	0.817								
Tea	1	0.201								
	7	0.000	0.000	0.000	0.393	0.000	0.002	0.068	0.000	0.000
	14	0.000	0.863	0.301	0.000	0.264	0.006	0.034	0.000	0.863
	28	0.000	0.926	0.000	0.000	0.000	0.560	0.857	0.446	0.926
Coffee	1	0.011	0.155	0.902	0.083	0.289	0.064	0.237	0.491	0.155
	7	0.000	0.001	0.008	0.561	0.001	0.033	0.367	0.003	0.001
	14	0.006	0.439	0.713	0.597	0.001	0.872	0.004	0.007	0.439
	28	0.052								
Turmeric	1	0.022	0.127	0.141	0.093	0.889	0.002	0.108	0.123	0.127
	7	0.000	0.070	0.000	0.053	0.002	0.000	0.000	0.201	0.070
	14	0.003	0.141	0.001	0.496	0.967	0.005	0.001	0.522	0.141
	28	0.006	0.050	0.011	0.116	0.062	0.305	0.470	0.760	0.050

A. Ortho Technology, B. Ormco, C. Ortho Organizers, D. AO, E. Opal, F. G&H

Difference between companies

The difference of ΔE* values of elastomeric chains between different companies was minimal for the specimens immersed in the water but was more evident for those immersed in tea, coffee and turmeric solutions as seen in Fig. 1.

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 difference with the readings of Ormco, Ortho Organizers and Opal chains as shown in 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 as shown in 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 as displayed in 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 as shown in table 2.

Difference between dietary media

For all brands (Ortho Technology, Ormco, Ortho Organizer, AO, Opal and G&H), the elastomeric chains immersed in turmeric showed the highest color change reading peaking at 28 days' interval followed by the tea then coffee and lastly water which showed only minimal color change as shown in Fig. 2.

For all brands, ANOVA test showed a significant difference for all media and all time intervals, as seen in table 3.

The LSD test for the specimens immersed in water showed significant differences from those immersed in tea or coffee for all brands and at all-time intervals except at (1) day interval. However, LSD test for the specimens immersed in water showed significant differences from those immersed in turmeric solution for all brands and at all-time intervals.

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 interval for Ortho Technology, Ortho Organizer, AO and G&H and at (7) days for Ortho Organizer.

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 to measure the relative changes occurring throughout the whole period between visits.

A digital camera used to assess the amount of color change because of its reliability and accuracy. (Jarad *et al.,*2005) used a (5.0) megapixel camera and found a highly significant correlation between a spectrophotometer and digital camera for all CIE (L*a*and b*) coordinates.

The CIE (L*a* and b*) color space used for assessment of color changes. This system was commonly used in the assessment of small color differences (Da Silva *et al.,* 2013).

The discoloring effect of tea and coffee on elastic chains had extensively researched, but turmeric was added to this investigation because of its widely used in cooking. Recent researches had evaluated the discoloration effect caused by turmeric on ceramic brackets and elastic chains (Wriedt *et al.,* 2007) (Bhandari *et al.,* 2014).

Difference between companies

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

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

These differences might be because of several factors like the chemical composition and details of manufacturing and processing. The polyurethane used to make the elastic chains 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 (Brantley and Eliades, 2001). The surface characteristics such as texture and porosity could be different (Ardeshna and Vaidya Nathan., 2009).

To the author's knowledge, there is no published report on the discoloration of elastic chains. Therefore the comparison with other researches is not possible. However, previous researches on the discoloration of elastic modules also show a diversity in the intensity of discoloration caused by different media on the different brands of modules (Kim and Lee, 2009) (Ferrnandes *et al.,* 2012) (Cavalcante *et al.,*2013) (Bhandari *et al.,*2014).

In the present study, turmeric caused significantly more discoloration than tea and coffee. This agrees with previous studies (Ardeshna and Vaidyanathan, 2009).

But disagrees with the findings of other studies (Bhandari *et al.,* 2014) who found more discoloration of elastic modules caused by coffee than turmeric. The difference with (Bhandari *et al.,* 2014) may be because of the different response of modules than chains and the variable company brands.

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	0.000	0.084	0.133	0.000	0.811	0.000	0.000
	7	0.000	0.000	0.000	0.000	0.004	0.000	0.000
	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ormco	1	0.000	0.021	0.000	0.000	0.000	0.000	0.000
	′	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ortho Organizers	1	0.000	0.482	0.058	0.000	0.221	0.000	0.000
	7	0.000	0.000	0.001	0.000	0.180	0.000	0.000
	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AO	1	0.000	0.257	0.029	0.000	0.267	0.000	0.000
	′	0.000	0.000	0.000	0.000	0.014	0.000	0.000
	14	0.000	0.000	0.020	0.000	0.000	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Opal	1	0.000	0.478	0.000	0.000	0.000	0.000	0.000
	′	0.000	0.000	0.000	0.000	0.032	0.000	0.000
	14	0.000	0.000	0.000	0.000	0.001	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
G&H	1	0.000	0.088	0.009	0.000	0.320	0.000	0.000
	′	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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 (Ardeshna and Vaidyanathan, 2009) (Ferrnandes *et al.,* 2012) (Bhandari *et al.,* 2014). The difference may be because of the different chemical composition and manufacturing technique between elastic chains and modules.

Comparison between immersion times

Since all elastic pieces tested underwent a color change in the dietary media over time, the storage period was taken to assess staining degree. It was seen that the storage time influenced the amount of color change of the elastic chains and this was agreement with (Kim and Lee, 2009) (Bhandari *et al.,*2014).

Exposure to water led to chemical degradation of polyester polyurethane. Substances migrated from the elastic chains over time so that pigments and other compounds from dietary media penetrated deep into elastic chains and caused discoloration (Huget *et al.,* 1990) (Macedo*et al.,* 2012).

Thus when the elastic chains were stretched, the stretching affected the color stability of elastic chains giving the 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.,* 2014) who found the amount of discoloration increased when the amount of immersion time increased.

The discoloration amount caused by tea and coffee increased gradually to peak at (28) days. This agrees with the findings of (Bhandari *et al.,* 2014) who found similar findings on elastic modules. This disagrees with the findings of (Lew., 1990) who found the amount of discoloration of elastic modules increased rapidly.

Most of the discoloration caused by turmeric was on the first day. After this period, there was a trend towards saturation and reached a plateau at (7) days. This was in agreement with the findings of (Bhandari *et al.,* 2014) who found the same outcome on elastic modules.

Limitations of the study

1) In vivo staining differs from that found in vitro because of several factors like:
   a) Bacterial deposit on elastomeric chains.
   b) Surface roughness from abrasion due to occlusion and eating.
   c) The effect of salivary mucins and proteins.

d) The saliva in the oral cavity tends to dilute the concentration of the ingested dietary media. Also, it tends as a buffer for the PH of dietary media.

2) The difficulty technique to assess the color change of elastic chains because of the small surface area and slopes of the elastic chains.

Clinical consideration

We can recommend two points:

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 the minimum amount of discoloration to get benefits from choosing this type of appliance.
2) The orthodontist should use 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 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.
3) 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 reached a plateau at (7) days.

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