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Evaluation of Colour Stability in Orthodontic E-Chains in Various Solutions: An in Vitro Study

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Abstract **Original Research Article**

This in vitro study aimed to evaluate the colour stability of orthodontic elastomeric chains (E-chains) immersed in various solutions, simulating conditions encountered during orthodontic treatment. A total of 75 samples were divided into 5 groups based on the solutions used for immersion: control medium, chlorhexidine mouthwash, carbonated drink, honey lemon water and turmeric water in the time duration of 12hrs, 24hrs and 72hrs such as 5 samples per solution and time. The colour stability was assessed using the CIE L*ab** colour space system, and changes were quantified using the ΔE* (Delta E) formula. The results demonstrated significant differences in colour stability across the solutions. In descending order, the colour of the samples was: turmeric water, honey lemon water, carbonated drink, chlorhexidine mouthwash and control medium. The findings indicated that exposure to chromogenic solutions can adversely affect the aesthetic properties of E-chains, which may influence patient satisfaction and treatment outcomes. The study highlights the importance of understanding the impact of dietary habits on the aesthetic integrity of orthodontic E-chains. Further research is warranted to explore the long-term implications of these findings on orthodontic treatments and to investigate potential methods to enhance the colour stability of E-chains in clinical settings.
Keywords: Orthodontic clear e-chains, aesthetic, pigmentation, colour stability, CIELAB.

INTRODUCTION

In this evolving generation, physical reflect has become a superior concern to mankind. Facial features are the major carrier of this concern and dentition is an important component of this. Malocclusion is the cause for the change in facial features. This malocclusion can be corrected by orthodontic treatment. There are two types of orthodontic treatment: 1) Fixed 2) Removable. Fixed appliances are widely used as it is not depended on the patient for timely wear and management of the appliances. It is also much more efficient and effective method of moving the teeth compared to the latter. Fixed appliances consist of multiple component such as bands, brackets, arch wire, elastics, separators (Eliades T, 2007, Decusară *et al.*, 2022). These elastic components are changed during each visit. The elastic components come with great advantages including low cost, easy application, reduced chair time (Nakhaei *et al.*, 2017).

Synthetic elastics began to be produced in 1920 by petrochemical companies, and their use in orthodontics became widespread in 1960. Elastic chains (e-chains) are used for space closure in fixed orthodontic appliances (Silva *et al.*, 2021). E-chains are available in various inter ring distance as continuous, short and long. Chain elastics have different spacer chains. They are classified into short, medium and long types, according to the distance between the centre of two consecutive links, and may measure 3 mm, 3.6 mm or 4 mm, respectively (Quenzer JP *et al.*, 2015).

E-chains are made from clear resins or polyurethane (PUR). Polyurethane is manufactured from polyester or from polyhydrocarbon diols in combination with diisocyanate (Halimi A *et al*., 2012, Virdi G K *et al*., 2024). These polyurethane produces e-chains by die-stamping technique or injection moulding technique (Aldrees AM *et al*., 2015).

Ceramic brackets and clear e-chains and clear modules have gained high popularity due to their aesthetic concerns despite their disadvantages (Fernandes A. B *et al*., 2014, Ziuchkovski JP *et al*., 2008). But clear e-chains are susceptible to discolouration due to the consumption of different foods between each visit. The discolouration ranges depending on the type of food (Kawabata E *et al*., 2016).

The other major obstacle that practitioners face is the degradation of force given by e-chains. The level of degradation can be caused due to several factors such as time, internal factors (methods of manufacturing, inter ring distance, etc), environmental factors (temperature stored in, temperature of food intake, etc), sterilization method (Issa A. R *et al*., 2022, Chatla, Dr., 2022).

Aesthetics will always be the major concern for the patients to which the initiation of orthodontic treatment occurs. These ceramic brackets and clear e-chains helps the practitioners to achieve the goal of aesthetics. This will aid to improve the smile and confidence of an individual in many aspects thus by improving the quality of life (Padiyar, Narendra, 2010).

The major objective of this study is to evaluate the colour changes of clear orthodontic e-chian in different solutions.

MATERIALS AND METHODS

This study was approved by SRM medical college hospital and research centre- Institutional ethics committee (SRMIEC- ST0724-1467).

The clear e-chains are cut into segments containing links which measures 50mm each. The 5 solutions used for the study are artificial saliva, turmeric water, carbonated drink, honey lemon water and chlorhexidine mouthwash. The samples were observed at 3 different timings: being 12hrs, 24hrs and 72hrs respectively. 5 samples will be placed in each medium which is in total 75 samples (5*3=15) (15*5=75). The e-chains are to be immersed in each solution at 37℃ for the above mentioned 3 timings (Fig 1). The solutions should be changed every day. The e-chains are left to air dry. Digital images of the stained clear e-chains were taken during 12hrs, 24hrs and 72hrs in natural light at the same time of the day. The RGB (red, green and blue) values of the images are obtained using an eyedropper tool. Later these values are used to determine the CIELAB colour space. It is identified by the CIEDE2000 colour difference formula.

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

Fig 1: Immersion of clear e-chains in the 5 solutions for 12hrs, 24hrs and 72 hrs respectively

Statistical Methodology

All continuous variables calculated as mean and SD. Shapiro wilk test applied to check the normality. If the data had followed the non -normal applied to the non-parametric test. Kruskal Wallis test to apply the significant difference between three or more independent groups. Spearman rank correlation applied to check the correlation between two variables. The p value considered as <0.05. It was statistically significant.

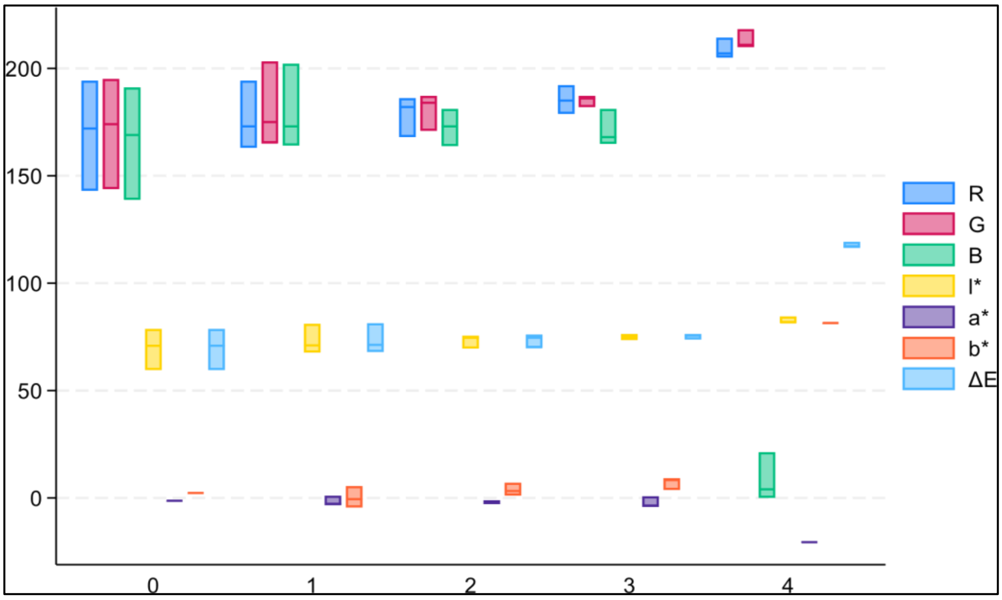
RESULT

The color changes in each solution is compared in Table 1 and Graph 1. Comparison of all variables (RGB, l*a*b*) in control medium, chlorhexidine mouthwash, carbonated drink, honey lemon water and turmeric water was a statistically significant. All six types of (R,G,B,l*,a*,b*) mean difference in all the solutions were statistically significant. The p value was 0.0070, 0.0060, 0.0056, 0.0046 and 0.0039 respectively for the solutions. There is a significant increase in the ΔE values between each solution. E-chains immersed in turmeric water has the greatest change in color.

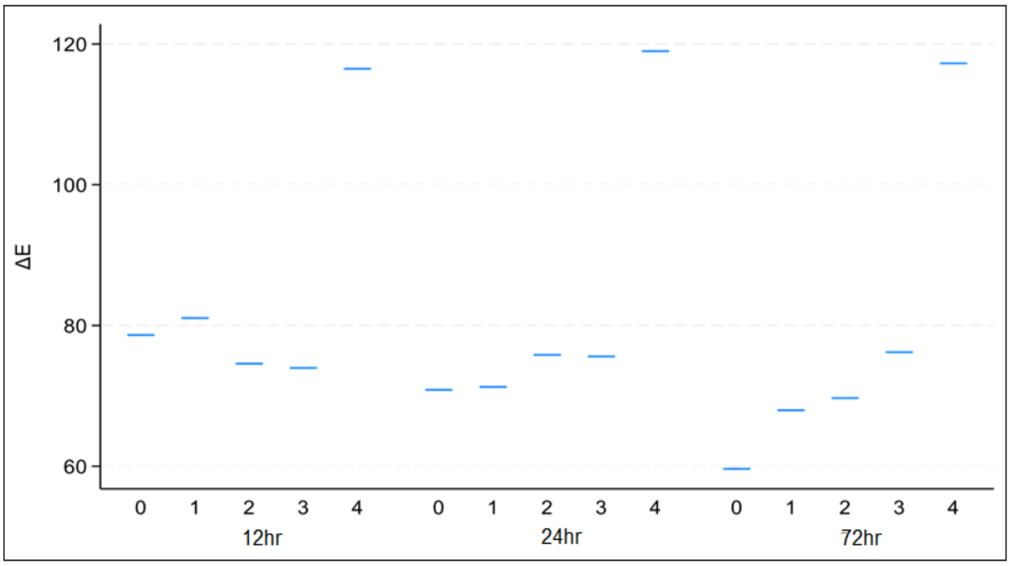
Table 1: Comparison of colour changes between each solution. Mean and standard deviation (in parenthesis) for R, G, B, l*, a*, b* values

	R	G	B	l*	a*	b*	ΔE	Total
Control medium	176.6(15.8)	181(19.6)	179.6(19.8)	73.3(6.87)	-1.71(2.23)	0.15(4.91)	73.4(6.80)	0.0070[k]
Chlorhexidine mouthwash	169.6(25.6)	171(25.6)	166.3(26.1)	69.6(9.57)	-1.35(0.2)	2.23(0.33)	69.7(9.55)	0.0060[k]
Carbonated drink	178.6(9.4)	180(8.50)	172.6(8.50)	73.1(3.17)	-2.17(0.83)	3.82(2.89)	73.4(3.24)	0.0056[k]
Honey lemon water	185.3(6.50)	185(2.64)	171.3(8.50)	74.8(1.37)	-2.33(2.62)	6.98(2.90)	75.2(1.15)	0.0046[k]
Turmeric water	208.6(4.73)	213(4.35)	8.33(11.2)	82.4(1.55)	-20.6(0.16)	81.3(0.42)	117.6(1.27)	0.0039[k]

k-Kruskal Wallis test



Graph 1: Values of R, G, B, l*, a*, b* of e-chains in each solution. (0- control medium, 1- chlorhexidine mouthwash, 2- carbonated drink, 3- honey lemon water, 4- turmeric water)



Graph 2: Comparison of ΔE among the different time pints. (0- control medium, 1- chlorhexidine mouthwash, 2- carbonated drink, 3- honey lemon water, 4- turmeric water)

Graph 2 presents ΔE of the e-chains in various solutions at different time intervals as 12hrs, 24hrs and 72hrs. E-chains immersed in turmeric water has the highest ΔE value in all the three durations.

The comparison between ΔE in different time durations is seen in Table 2. Comparison of a ΔE among the time point was not statistically significant. All the time point of mean difference was statistically significant in ΔE. The p value was 0.4025.

Table 2: Comparison between ΔE in different time durations. Mean and standard deviation (in parenthesis)

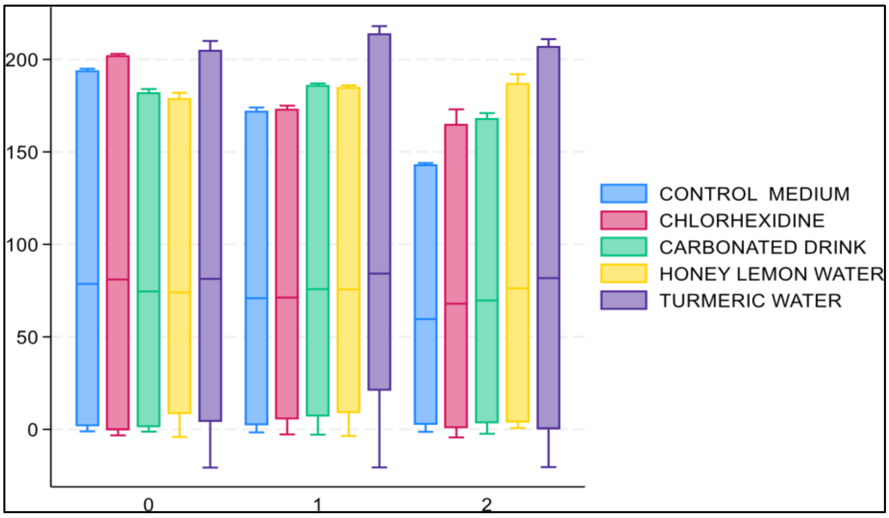
Time (in hrs)	ΔE
12	84.9(17.8)
24	82.5(20.5)
72	78.4(22.6)
P value	0.4025^{k}

Table 3: Comparison of Correlation between Δ*E* & different colours of different time hours

Correlate with ΔE	R	G	B	l*	a*	b*
12hrs Rho P value	 0.9747 0.0110	 1.0000 0.0082	 0.0000 1.0000	 1.0000 0.0082	 -0.3000 0.6510	 0.1000 0.8694
24hrs Rho P value	 1.0000 0.0082	 1.0000 0.0082	 -0.3000 0.6150	 1.0000 0.0082	 -0.9000 0.0468	 0.9000 0.0468
72hrs Rho P value	 1.0000 0.0082	 1.0000 0.0082	 -0.1000 0.8694	 1.0000 0.0082	 -0.5000 0.3819	 -0.9000 0.0468

The correlation between ΔE and different variables of different time hours is noted in Table 3. The R value was highly positive correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was statistically significant. The p value was 0.0110, 0.0082 and 0.0082 respectively. The G was highly positive correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was statistically significant. The p value was 0.0082, 0.0082, 0.0082 respectively. The B was low negative correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was not statistically significant. The p value was 1.0000, 0.6150 and 0.8694 for the respective timings. The l* was highly positive correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was statistically significant. The p value was 0.0082, 0.0082, 0.0082 respectively. The a* was medium negative correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was statistically significant for 24hrs and not significant for 12hrs and 72hrs. The p value was 0.6510, 0.0468 and 0.3819 for 12hrs, 24hrs and 72hrs respectively. The b* was medium positive correlated between the Δ*E* in 12hrs, 24hrs and 72hrs. It was statistically significant for 24hrs & 72hrs and not significant for 12hrs. The p value was 0.8694, 0.0468 and 0.0468 for 12hrs, 24hrs and 72hrs respectively.

Graph 3 represents the overall colour changes that occurs in different time durations. In this turmeric water has caused major colour changes in the e-chains. It then followed by honey lemon water, carbonated drink and chlorhexidine lastly.



Graph 3: Comparison of overall e-chains immersed in various solutions among the three different time points

DISCUSSION

The null hypothesis was rejected as colour changes was seen in the clear e-chains after immersion in the solutions for 12hrs, 24hrs and 72hrs. There were significant changes between the e-chains in various solutions. The solutions used are commonly consumed foods so, this has a great disadvantage in the world of orthodontics as aesthetic comes as the major concern to a person (Silva, V. D. D *et al*., 2018, Dias da Silva, V *et al*., 2016).

All solutions have changed the final aspect and colour of all the tested orthodontic clear e-chains. In descending order, the colour of the samples was: turmeric water, honey lemon water, carbonated drink, chlorhexidine mouthwash and control medium.

A similar study was conducted by Ardeshna and Vaidyanathan measured colour stability of clear and coloured elastomeric chains from different companies exposed to coffee, cola, tea and spices for 72 hrs using Minolta chromameter. Similar to the results obtained by this study, they observed significant changes in the colour which included the grey level and chromaticity (Ardeshna, A. P *et al*., 2009).

Kim and Lee conducted a study using digital photographs and commercial software to analyze the colour changes in three types of clear orthodontic elastomeric modules after being submerged in 2% methylene blue. The modules were evaluated over time intervals ranging from a few hours to five days, and their results showed that the type of elastomeric modules, as well as the duration and immersion solution, significantly affected the degree of discoloration. Similarly, this study produced comparable findings, showing that the solutions of immersion and the time interval had a notable impact on the discoloration patterns observed (Kim, S. H *et al*., 2009).

Turmeric water exhibited the highest degree of discoloration, likely due to its rich chromogen content, which can easily penetrate the elastomeric matrix and cause visible staining. Honey lemon water followed, showing considerable discoloration, possibly attributed to its acidic nature, which may weaken the material structure and allow for deeper penetration of staining agents. Carbonated drinks also contributed to discoloration, as their acidic composition can soften the elastomer and facilitate colour change.

Chlorhexidine, while commonly used as an oral antiseptic, resulted in moderate discoloration. Although its primary purpose is therapeutic, the study indicates that clinical agents can still affect the aesthetic quality of orthodontic materials. Lastly, the control medium demonstrated the least discoloration, affirming its neutral effect compared to the other solutions tested.

The CIELAB is calculated by CIEDE2000. When the CIELAB was used to determine the ΔE value, a great increase in the value was seen in the e-chains immersed in turmeric water and decreased from it in the order of honey lemon water, carbonated drink, chlorhexidine mouthwash and control medium (Johnston WM, 2009).

Overall, these findings underscore the role of dietary habits in the aesthetic durability of orthodontic materials. Patients may benefit from guidance on reducing intake of pigmented or acidic beverages to help preserve the appearance of their orthodontic appliances (MIRANDA *et al*., 2021). Future research should explore alternative material compositions and protective coatings aimed at improving the colour stability of orthodontic elastomeric in the presence of common dietary stains.

CONCLUSION

This study evaluated the colour stability of orthodontic E-chains in various solutions, including a control medium, chlorhexidine, carbonated drinks, honey lemon water, and turmeric water. The results revealed significant differences in discoloration levels, with turmeric water causing the most severe staining, followed by honey lemon water, carbonated drinks, and chlorhexidine, while the control medium exhibited minimal discoloration.

These findings highlight the substantial impact of both dietary and clinical exposures on the aesthetic properties of orthodontic materials. It is crucial to educate patients about the potential staining effects of certain foods and beverages, especially those that are pigmented or acidic. Providing guidance on minimizing exposure to these solutions can help maintain the visual integrity of orthodontic appliances throughout treatment.

Future research should focus on developing alternative materials and protective coatings that enhance the colour stability of orthodontic E-chains, thereby improving aesthetic outcomes and increasing patient satisfaction during orthodontic care.

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