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Comparison of color stability of different coated esthetic orthodontic archwires using spectrocolorimeter – An invitro study

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ABSTRACT

Aim: The aim of this study was to evaluate and compare the colour stability of three different esthetic archwires (rhodium, teflon and epoxy coated) immersed in three different staining solutions (tea, coffee and artificial aerated orange drink) at different time intervals (0^{th}, 7^{th}, 14^{th}, 21^{st}, 45^{th} day) using spectrocolorimeter and also to determine the most chromogenic agent.

Materials and Methods: A total of 54 esthetic coated archwires (rhodium, teflon and epoxy) were evaluated. They were divided into 3 groups (archwires) with each group having 3 subgroups (staining solutions) and six samples in each sub group. The baseline value (T0) was measured before the samples were immersed in the staining solutions. The samples were immersed in the staining solution for 3 hours a day for 45 days. The ΔE values were recorded on 7^{th}, 14^{th}, 21^{st} and 45^{th} day using spectrocolorimeter. Using these values NBS units were calculated. The experimental data were analyzed using descriptive statistics, analysis of variance, and post hoc Bonferroni test.

Results: It was found that teflon coated esthetic archwires were the least colour stable when compared with rhodium and epoxy coated esthetic archwires. Artificial aerated orange drink caused higher ΔE* values than tea and coffee. The ΔE* value increases as the time interval increases.

Conclusions: All esthetic archwires evaluated in the present study were stained the most by an artificial aerated orange drink in comparison with coffee and tea. The overall study outcome indicates that archwires coated with epoxy resin are more advisable for patients because of their colour stability.

1. Introduction

In recent years, there has been an increase in the number of adult patients who are seeking orthodontic treatment.[1] Accordingly, there is a demand for more esthetically pleasing treatment options such as ceramic braces, clear aligners and lingual orthodontics, among these ceramic braces is a common choice.[2] The ultimate goal in developing an appliance is to provide adequate technical performance for the clinician with acceptable esthetics for the patient.[3]

The introduction of tooth coloured, coated archwires provides good esthetic appearance to the patient. The colour of esthetic archwires should preferably correlate to that of natural teeth and brackets.[4] The coating of these archwires is mainly composed of polytetrafluoroethylene,[5] rhodium,[6] epoxy resin,[6] polyphenylene polymers,[7] and fibre reinforced composites.[8,9] During orthodontic treatment, the colour stability of esthetic archwires is clinically important. However, some authors have suggested that esthetic coated orthodontic archwires tend to discolour over a period of time.[8,10]

The discolouration of esthetic archwires is mainly caused by internal and external factors.[11] The reasons for internal discolouration is ultraviolet irradiation and

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thermal energy.[11] External discolouration can be caused by numerous factors such as food dyes, coloured mouth rinses[11] etc. A variety of factors, including oral hygiene, water absorption, and incomplete polymerization, can also affect the amount of colour change.[12] Some of the commonly consumed food dyes which cause discolouration of the esthetic archwire are tea,[11] coffee,[13] red wine,[14] turmeric powder[15] and artificial coloured aerated drinks.[14]

Very few studies have compared the colour stability of rhodium, teflon and epoxy coated esthetic archwires in commonly consumed beverages. Therefore, this in-vitro study was undertaken to analyze the colour stability of rhodium, teflon and epoxy coated esthetic archwires when immersed in common staining solutions such as tea, coffee and artificial aerated orange drink for 7, 14, 21 and 45 days.

2. Aim

To evaluate and compare the colour stability of three different esthetic archwires immersed in three different staining solutions at different time intervals using spectrocolorimeter and also to determine the most chromogenic agent.

3. Materials and Methods

The study was performed in the Department of Orthodontics and Dentofacial Orthopaedics, Indira Gandhi Institute of Dental Sciences, SBV University, Pillayarkuppam, Puducherry. The study was conducted for a period of 45 days on approval from Institutional Review Board and Institutional Ethical Committee (IEC Approval Code: IGIDSIEC2018NRP43PGNOODO). The physical tests were performed at Central Inter-Disciplinary Research Facility (CIDRF), Sri Balaji Vidyapeeth (SBV), Puducherry.

The study included esthetic archwires which were without any manufacturing defects or any visible indentations. The following esthetic archwires; rhodium coated (OrthoOne), teflon coated (JJ Orthodontics) and epoxy coated (Libral traders) were used in this study.

The esthetic archwires which had defects such as wear, roughness, granulations, indentations, bulges and deficiency of coating were excluded from the study.

3.1. Sample size determination

From the review of literature,[14] the sample size was determined as n=6, with the α error fixed to 0.05 and with a power of 80% and was calculated using the formula.

$$n = \frac{2\sigma^2(Z_{1-\beta} + Z_{1-\alpha/2})^2}{(\mu_1 - \mu_2)^2}$$

3.2. Preparation of sample

The esthetic coated archwires were cut into 10-mm-long sections. Ten of these cut sections were held adjacent to each other in a row and the ends of these wires were fixed with flowable resin (Tetric N-Flow, Ivoclar Vivadent) (Figure 1). The width of each sample was 10 mm so that colour could be easily measured using spectrocolorimeter. The evaluation of colour stability was done with spectrocolorimeter at Central Inter-Disciplinary Research Facilities, MGMCRI, Puducherry.

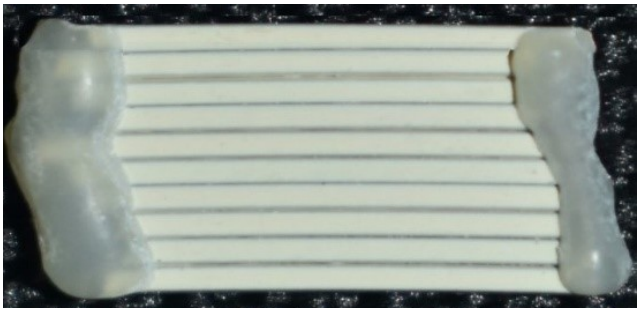

Fig. 1:

3.3. Staining solutions preparation

3.4. Preparation of coffee

It was prepared by pouring 15 ml (1 tablespoon) of boiling distilled water over 2.4 gm of coffee powder (Bru instant sachet, Hindustan Unilever Ltd, India) and 1 teaspoon of sugar, stirred for 2 minutes followed by adding 150 ml of boiling milk. The solution was freshly prepared every day using standardized measurements by the same investigator (Figure 3).

Fig. 2:

3.4.1. Preparation of tea

Tea was prepared by boiling a tea bag (1.9 gm, Taj Mahal, Brooke bond, Hindustan Unilever Ltd, India) in 100ml water for 3 mins, 100ml boiling milk and 1 teaspoon sugar (4.8 gm) were added to the tea and was allowed to boil for an additional 2 minutes. The solution was freshly prepared every day using standardized measurements by the same investigator (Figure 3).

Fig. 3:

3.4.2. Preparation of artificial aerated orange drink

Artificial aerated orange drink (Fanta) stored at room temperature (about 37°C) had been used and replaced once daily to prevent precipitation (Figure 3).

3.4.3. Colour measurement

The colour measurements of the study samples were measured using spectrocolorimeter (RM200 QC, x-rite) (Figure 4). The study samples were stored in distilled water at 37° C for 24 hours. Before immersing the study samples into the staining solutions, the baseline (T0) value of each sample was measured using spectrocolorimeter. After the baseline measurement (T0), the individual samples were immersed in 20 ml of the prepared staining solutions in individual test tubes, 3 hours per day for 45 days, and the solution was changed every day to prevent precipitation of the solution. Every day, after the daily immersion time of 3 hours, the specimens were removed from the solution, rinsed with distilled water for 5 minutes in an ultrasonic cleaning bath (Codyson Intertek GS, Ultrasonic Cleaner CD4890(Figure 5), China), dried with tissue paper, and stored in a container at 37°C until the next daily treatment. The colour measurements were done on 7^{th}, 14^{th}, 21^{st} and 45^{th} day and recorded as T1, T2, T3 and T4 respectively. The spectrocolorimeter was calibrated according to the manufacturer's instructions prior to the measurements. To standardize the measurements the samples were placed on the same white background. Four readings were made from each sample by a professional examiner. The CIE L*a*b * colour system was used to describe the colour changes.

Fig. 4:

Fig. 5:

Total colour differences are expressed by the formula

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

Where, △L*, △a*, and △b* were differences in L*, a*, and b* values before (T0) and after immersion at each time interval (T1, T2, T3 and T4).

To relate the amount of colour change (△E*) to a clinical environment, the data was converted to National Bureau of Standards (NBS) units as follows:

NBS Unit Definitions of Colour Differences

NBS units = △E* x 0.92

These values were suggested by Koksal and Dikbas[16] and are shown in Table 1.

Table 1: Critical marks of colour change according to the national bureau standards

0.0–0.5	**Trace**	**Extremely slight change**
0.5–1.5	Slight	Slight change
1.5–3.0	Noticeable	Perceivable change
3.0–6.0	Appreciable	Marked change
6.0–12.0	Much	Extremely marked change
12.0+	Very much	Change to another colour

3.5. Statistical analysis

Data obtained was tabulated and subjected to statistical analysis using SPSS 24 version software. The △E and NBS values were calculated using mean and standard deviation. For intergroup comparison one-way ANOVA was used and for intragroup comparison repeated measures ANOVA was used. p-value of 0.05 was considered as statistically significant. Post hoc Bonferroni test were carried out for p value < 0.05.

4. Results

The results as tabulated in Table 2 shows the total colour change values (ΔE* values) and National Bureau of Standards (NBS) units of the esthetic archwires at different time intervals of immersion in three staining solutions. It was found that teflon coated esthetic archwires were the least colour stable when compared with rhodium and epoxy coated esthetic archwires. Artificial aerated orange drink caused higher ΔE* values than tea and coffee. The ΔE* value increases as the time interval increases. Moreover, most of colour changes of the esthetic archwires that were caused by artificial aerated orange drink, tea, and coffee were clinically unacceptable and represented graphically (Figures 6, 7 and 8) which shows the effect of the staining solutions and immersion time on esthetic archwires. It was found that there were high significant differences in colour changes (ΔE* values) among all staining solutions at all time intervals.

5. Discussion

The tooth-coloured archwires have produced a lot of interest in orthodontics and are in growing demand in contemporary orthodontics. Since then, several in vivo and in-vitro studies have conducted on the clinical efficiency of the esthetic archwires. The colour of esthetic archwires should preferably conform to that of natural teeth since it differs according to race, sex and age.[13] It is difficult for the naked human eye to distinguish the minor colour changes. As instrumental measurements eliminate the

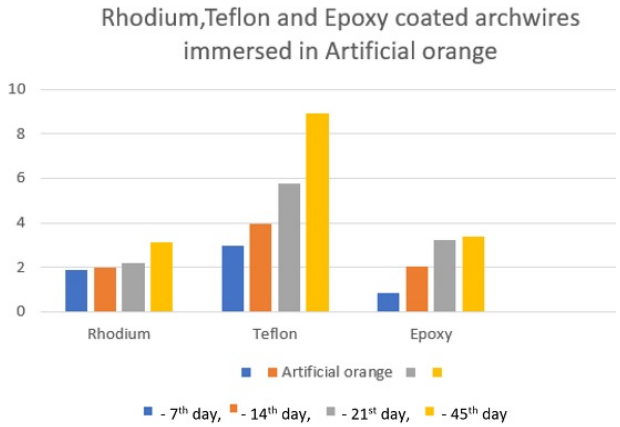

Fig. 6: Rhodium, teflon and epoxy coated esthetic archwires immersed in artificial orange in NBS units

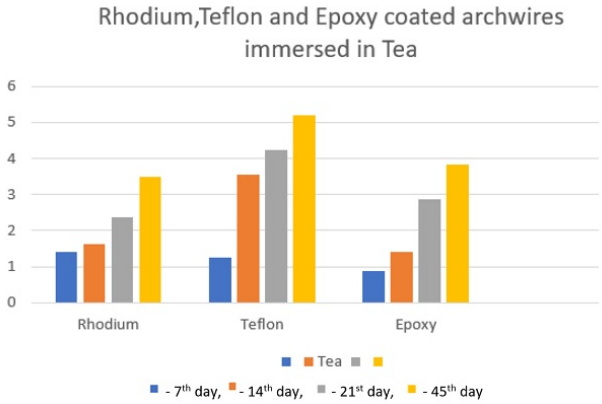

Fig. 7: Rhodium, teflon and epoxy coated esthetic archwires immersed in tea in NBS units

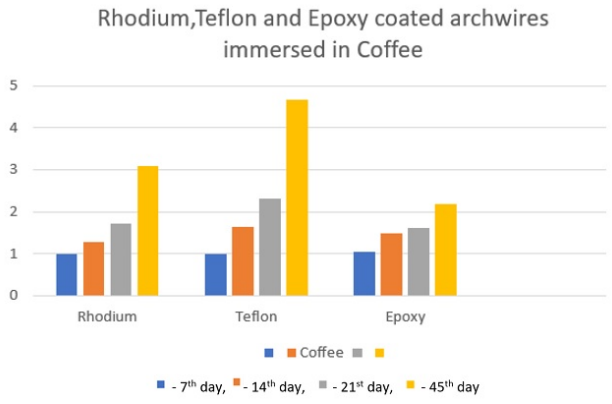

Fig. 8: Rhodium, teflon and epoxy coated esthetic archwires immersed in coffee in NBS units

Table 2: NBS units for rhodium, teflon and epoxy coated esthetic archwires in 3 different staining solution

Wire	Solution	Day 7	Color Change	Day 14	Color Change	Day 21	Color Change	Day 45	Color Change
Rhodium	Artificial orange	1.88	Noticeable	2.00	Noticeable	2.19	Noticeable	3.13	Appreciable
	Tea	1.42	Slight	1.61	Noticeable	2.38	Noticeable	3.50	Appreciable
	Coffee	1.00	Slight	1.27	Slight	1.72	Noticeable	3.08	Appreciable
Teflon	Artificial orange	2.97	Noticeable	3.97	Appreciable	5.74	Appreciable	8.92	Much
	Tea	1.26	Slight	3.56	Appreciable	4.24	Appreciable	5.21	Appreciable
	Coffee	1.00	Slight	1.63	Noticeable	2.32	Noticeable	4.66	Appreciable
Epoxy	Artificial orange	0.84	Slight	2.01	Noticeable	3.20	Appreciable	3.39	Appreciable
	Tea	0.87	Slight	1.40	Slight	2.87	Noticeable	3.83	Appreciable
	Coffee	1.05	Slight	1.47	Slight	1.61	Noticeable	2.18	Noticeable

subjective perception of visual colour comparison, the spectrocolorimeter is used.

Rhodium, epoxy, teflon, fiber reinforced composite (FRC), glass-fiber-reinforced plastics (GFRPs)[16] are some of the commonly available esthetic coated archwires. Various authors have compared the colour stability of Teflon[14,17] and epoxy[14,17] coated esthetic archwires. But very few studies were conducted on rhodium coated esthetic archwire. Thereby, in this study, teflon, epoxy and rhodium coated esthetic archwires were selected. The study periods by various authors ranged from 2 to 6 weeks.[6,13,14,16–20] Since the duration between each orthodontic appointment typically ranges from 4 to 8 weeks,[21] the present study aimed to evaluate the colour changes during a period of 45 days, with the samples being immersed in the staining solution for 3 hours a day, and the measurements were taken at time intervals of 7, 14, 21 and 45 days, so as to determine when the first colour change appears. We have chosen 3 hours a day of immersion of the samples so as to closely simulate the oral environment.[17]

In the present study, teflon coated archwires discoloured the most when compared with rhodium coated and epoxy coated archwires. Teflon coated archwires have shown much colour change on 45^{th} day in artificial aerated orange drink. Similar findings were found in studies carried out by Anand A,[14] Hussein and Ghaib,[4,22] Rego et al[17] and Alsanea and Al Shehri.[6] All these studies substantiate that the teflon coated esthetic archwires were most susceptible to the colour change when immersed in different dietary staining solutions. The possible reason for increased colour change of teflon coated archwires may be due to its manufacturing process.[23]

The ΔE value for an artificial aerated orange drink was highest when compared with tea and coffee. The reason for this may be due to the additional colouring agents used in the artificial orange drink.[24] In a study conducted by Anand A, the highest ΔE value obtained for red wine followed by artificial aerated orange drink and mouthwash. Though red wine causes much discolouration it is not a commonly consumed beverage in the Indian population and hence was not included in our study. Numerous studies have been conducted on cola drinks and very few studies were conducted on artificial aerated orange drink. Therefore, in the present study artificial orange along with coffee and tea were selected as the staining solutions.

Coffee has been found to be the most chromogenic agent in most of the previous studies,[13] while in our present study artificial orange was found to be the most chromogenic. This could be attributed to the fact that according to our literature search no studies have been conducted to compare these two agents. Another possibility that coffee was less staining in our study could probably be due to the addition of milk for the preparation of coffee or tea as it is the usual way of consumption in India, while coffee and tea in its concentrated form is usually evaluated.[25]

6. Limitations

The present study was performed in an in-vitro environment. An attempt has been made to simulate the oral environment, but its simulation always remains complex and cannot be accurately reproduced in an in-vitro setting. An in-vivo research would be ideal, but several confounding factors could play a role in the results of the study, including dietary variance, oral hygiene, amount of chewing and salivary composition. The differences in thickness and surface characteristics of the esthetic orthodontic archwires may also add impact on the colour measurements.

7. Scope of the Study

Future studies might be conducted in-vivo by monitoring the dietary intake and beverage consumption of the patient through a valid dietary assessment.

8. Conclusion

The present study concluded that all esthetic orthodontic archwires showed clinically noticeable colour changes after 21 days of immersion in staining solutions. Teflon coated esthetic orthodontic archwires demonstrated significant colour changes which were appreciable colour change according to NBS definition as early as 14 days (artificial orange and tea) of immersion in staining solutions. The archwires coated with epoxy resin were more colour stable than the rhodium and teflon coated esthetic archwires. All the esthetic archwires evaluated in the present study were stained the most by an artificial aerated orange drink in comparison with coffee and tea. The overall study outcome indicates that archwires coated with epoxy resin are more advisable for patients because of their colour stability. Further studies are needed to evaluate other material characteristics and fluorescence of the esthetic coated archwires. In conclusion rhodium, epoxy and teflon coated esthetic orthodontic archwires showed colour changes at variable degrees, therefore patients need to be counselled to not consume the foods/beverages containing chromogenic agents so as to prevent the discolouration of the esthetic archwires and also to avoid frequent changes of the same due to esthetic reasons.

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