Color stability of orthodontic esthetic archwires- A comparative in vitro study

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Abstract

Objective: To study and evaluate effect of various food products on color stability of orthodontic esthetic archwires at different time period.

Materials and Methods: A total of 120 coated esthetic archwires (Teflon and Epoxy Resin) were investigated. They were divided into 4 groups and 8 subgroups. Cumulative discoloring effect of staining agents (aerated drink artificial orange, colgate plax mouth wash, and red wine) and control group in distilled water were analyzed for a period of 21 days and the solution was changed every 7^{th} day. Samples were analyzed with spectrophotometer to obtain the L*, a*, and b* (lightness, red-green, and yellow-blue) color readings. Using these values total color change (ΔE*) at each level was also calculated. A general linear model (ANOVA and Tukey's Post Hoc) test was used for statistical comparisons.

Results: Significant differences were observed in ΔE value of teflon and epoxy resin coated esthetic archwires between the staining agent and the control groups ($p \leq .0001$). Among the teflon coated esthetic archwires the ΔE value for Artificial orange (aerated drink) (5.61±0.30) was highest indicating that artificial orange discolored the wires most in the inter group followed by the red wine (5.44±0.25), and colgate plax mouthwash (1.31±0.15) the least. Among the epoxy resin coated esthetic archwires the ΔE value for red wine (4.52±0.30) was highest indicating that wires in the red wine discolored most. The colgate plax mouthwash (3.54±0.15) and the artificial orange (3.42±0.14) almost stain same. On overall comparision teflon coated and epoxy resin coated, the mean ΔE value was statically significant in all the experimental groups. But the epoxy resin coated esthetic archwires were less stained as compare to Teflon coated wires (p value <0.001**).

Conclusion: Both teflon coated and epoxy resin coated archwires showed changes in colour when exposed to staining agent. In the present study the epoxy resin coated archwires were more color stable than the teflon coated wires.

Keywords: Teflon coated archwire, Epoxy Resin coated archwires, Color stability, Esthetic archwires, Coating stability.

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 an appliance that combines both acceptable aesthetics for the patient and adequate technical performance for the clinician is the ultimate goal.[1]

Although orthodontic therapy can significantly improve dentofacial appearance, the discipline has historically received a poor reputation for esthetics because of the appliances required during treatment. "Metal mouth" seems to be irrevocably tied to orthodontic therapy. With increasing number of adults seeking orthodontic treatment, the unsightly appearance of metallic fixed orthodontic appliance has become a major concern and as a result aesthetic appliances have been introduced to satisfy clinical demands.[3]

This problem has been partially solved by the introduction of esthetic brackets made of ceramic or composite. The archwire, which is one of the main parts of a multibracket appliance, is designed to move teeth from malocclusion to a preferred dental occlusion through mechanical interaction with the bracket slots.[4]

Some of the esthetic wires available are metal wires with white teflon or epoxy resin on the surface or composite material using a polymer for the matrix and glass fibres for reinforcement.[5] Plastic resin materials such as synthetic fluorine-containing resin or epoxy resin composed mainly of polytetrafluoroethylene to simulate tooth colors are used.[2]

Discolouration of orthodontic materials may be due to intrinsic factors such as water sorption, incomplete polymerization of adhesives or resins, matrix composition of the material, content and size of reinforcement particles, brands, tone, or extrinsic factors as ingestion of coloured food materials such as, coffee, tea, colas, mouthwash, nicotine and lipstick. Fluoride ions in the prophylactic agents like mouthwashes have been reported to cause corrosion, discolouration and alteration of the mechanical properties of orthodontic wires. The polymeric structure and surface roughness play decisive roles in the extent of discoloration caused by various substances.[5]

The amount of color change can be influenced by a number of factors, including oral hygiene and water sorption. Clinical perceptibility of color differences has been the subject of numerous investigations. The Commission Internationale de l'Eclairage (CIE) recommended calculating color difference (ΔE) based on CIELAB color parameters. The ΔE values are used to describe whether the changes in the overall shade are perceivable to the human observer. This magnitude of the color difference is based on the human perception of color; color differences greater than 1 ΔE unit are visually detectable by 50% of human observers.[6]

However, under uncontrolled clinical conditions, such small differences in color would be unnoticeable because average color differences below 3.7 have been rated as a match in the oral environment. Hence this study is being done to evaluate & compare the color stability of esthetic coated wires by using different food products under spectrophotometer.[7]

Materials and Methods

This was an in vitro study conducted on orthodontic esthetic wire specimens, in controlled laboratory.

Source of data:

1. Orthodontic aesthetic wires
2. Distilled water (C)
3. Aerated drink (artificial orange) (C1)
4. Colgate plax mouthwash (C2)
5. Red wine (C3)
6. Petridishes
7. Spectrophotometer

Orthodontic Esthetic Wires

This study was done on 120 specimen of orthodontic esthetic wires.

The wires used in this in-vitro study are:

1. Teflon coated Rectangular esthetic archwires (Prime Ortho)
2. Epoxy resin coated Rectangular esthetic archwire (Canadian Orthodontics)

They were again divided into 4 groups and 8 subgroups:

Group 1: {control group}; immersed in de-ionized water.

Subgroup A_1: Teflon coated esthetic archwire immersed in water.

Subgroup A_2: Epoxy resin coated esthetic archwire immersed in water.

Group 2: {experimental group}; immersed in aerated Artificial Orange drink.

Subgroup B_1: Teflon coated esthetic archwire immersed in orange drink.

Subgroup $B_{2:}$ Epoxy resin coated esthetic archwire immersed in orange drink.

Group 3: {experimental group}; immersed in red wine.

Subgroup C_1: Teflon coated esthetic archwire immersed in red wine.

Subgroup C_2: Epoxy resin coated esthetic archwire immersed in red wine.

Group 4: {experimental group}; immersed in mouthwash. Subgroup

$D_{1:}$ Teflon coated esthetic archwire immersed in mouthwash.

D_2: Epoxy resin esthetic archwire coated immersed in mouthwash

These wires were immersed in various solutions like distilled water, artificial orange, mouthwash, wine (Fig. 1) for 21 days. All the solutions were changed after every 7 days, after 21st day the wires were cleaned with distilled water in an ultrasonic cleaning bath for 5 minutes. Excess water on the surfaces were removed with tissue papers, and the samples will be allowed to dry. Color measurements were taken after testing on the 21^{st} day and the color measurement were done with the spectrophotometer. For the control value, or the base value, each wire group was analysed for its original color value at 0 day interval, before its immersion into the solution. The values were recorded and were taken as the standard values for the further comparision with the experimental groups. After 21 days wires from the experiment groups were analysed for its color change. The values were recorded with comparision from the control value.

Data Collection: Color differences are measured as the Euclidian distance between the two points of measurement in the three dimensional space, referred to as ΔE. The color change reading was taken by means of the software attached to a computer with a previously established configuration, and the value of ΔE* was automatically obtained for each wires in each experimental period, generating a mean ΔE* for each wire brand and solution. The higher the ΔE* value, the bigger the difference in color and hence the more perceptible the difference is to the human eye. The color measurements were carried out using the Datacolor 650 spectrophotometer (Fig. 2) with a pinhole diaphragm diameter of 4 mm. The Datacolor650 has ultra-precise reflectance and transmittance measurements.

A spectrophotometer (Fig. 2) is a device that consists of three principle elements: a light source; a means to direct the light source to an object and receive the light reflected or otherwise returned from the object; and a spectrophotometer that determines the intensity of received light as a function of wavelength. Spectrophotometer can collect light that reflects from the material surface and translate it into three color coordinates. Those are the three numbers that exactly describe a position of the color in the 3D color space. The wavelength is 300 nm to 700nm. The color specification system for use in dentistry is the CIE-L*a*b* color system. CIE stands for the Commission Internationale de l'Eclairage. The reason for the introduction of the L*a*b* model was the need to make uniform distances between two color stimuli, in order to be able to define the exact color difference (ΔE*). According to the

CIE L * a * b * system (Commission Internationale de l'Eclairage, 1976), a color graph consisting of L *, a *, and b * co-ordinates can be produced by means of mathematical transformations. The L * parameter corresponds to the degree of lightness and darkness and the a * and b * values to the chroma, where + a * is red, − a * is green, + b * is yellow, and − b * is blue.

The calculation Δ E * between two colour positions in the three-dimensional L * a * b * colour space is as follows:

$\Delta E^* = [(L1^* - L2^*)2 + (a1^* - a2^*)2 + (b1^* - b2^*)2]\ 1/2$

L1 = initial value a1= initial value b2 = initial value
L2= final value a2= final value b2 = final value

The obtained values were then subjected to statical analysis.

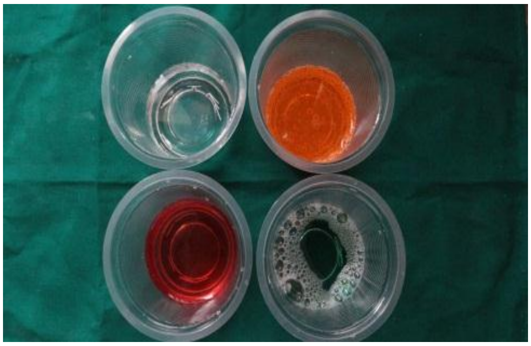


Fig. 1: Wires in distilled water, artificial orange, mouthwash, wine

Fig. 2: Spectrophotometer

Results

A total sample comprising of 120 wires were used in this study comprising group1, group 2, group 3, group 4. These groups were divided into 8 subgroups with 15 wires each as per the solutions they were immersed. The color measurement was carried out using the spectrophotometer according to the CIE L*a*b* system. The results and the static values are enumerated in the form of tables and graph. The mean and standard deviations of the corrected *ΔE* values are given for the experimental and control groups.

Table 1:

Comparison of mean CIE DE Values on the 1st Day after immersing into different colorant solutions between teflon & epoxy resin wires using Student unpaired t Test								
Colorants	Wire	N	Mean	SD	S.E.M	Mean Diff	t	P-Value
Orange	Teflon Wire	15	2.74	0.04	0.01	1.51	25.361	<0.001*
	Epoxy Wire	15	1.23	0.23	0.06			
Mouth wash	Teflon Wire	15	1.09	0.21	0.05	-1.32	- 17.370	<0.001*
	Epoxy Wire	15	2.42	0.21	0.05			
Wine	Teflon Wire	15	2.30	0.16	0.04	-0.27	-5.160	<0.001*
	Epoxy Wire	15	2.56	0.12	0.03			

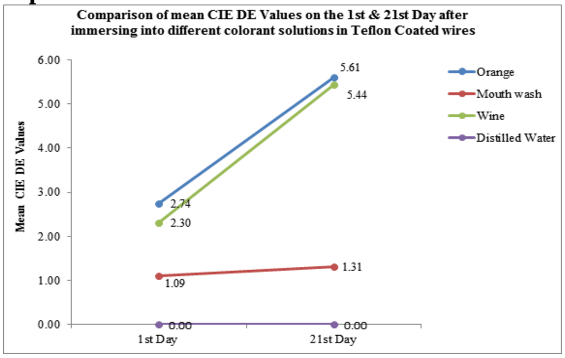
Students Unpaired t-test

Table 2:

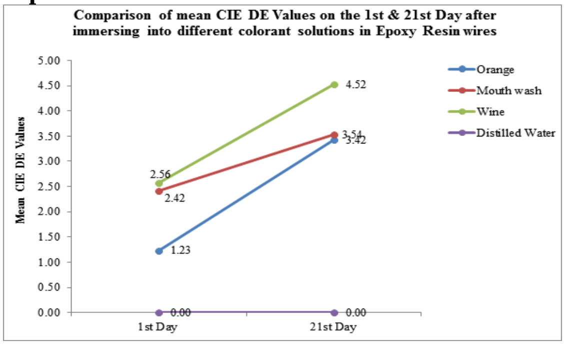
Comparison of mean CIE DE Values on the 1st & 21st Day after immersing into different colorant solutions in teflon coated wires using Student Paired t Test								
Colorants	Time	N	Mean	SD	S.E.M	Mean Diff	t	P-Value
Orange	1st Day	15	2.74	0.04	0.01	-2.86	-37.523	<0.001*
	21st Day	15	5.61	0.30	0.08			
Mouth wash	1st Day	15	1.09	0.21	0.05	-0.21	-3.237	0.006*
	21st Day	15	1.31	0.22	0.06			
Wine	1st Day	15	2.30	0.16	0.04	-3.14	-36.871	<0.001*
	21st Day	15	5.44	0.25	0.06			

Students Paired t- test

Graph 1:

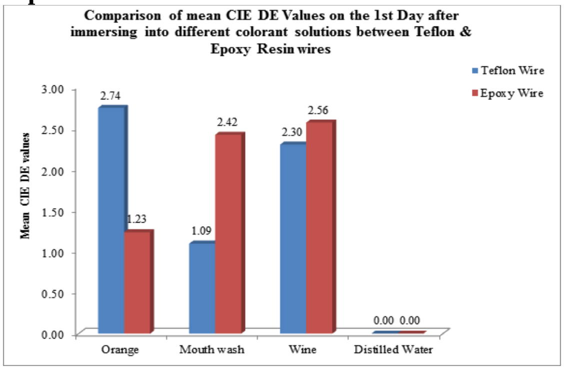


Graph 2:

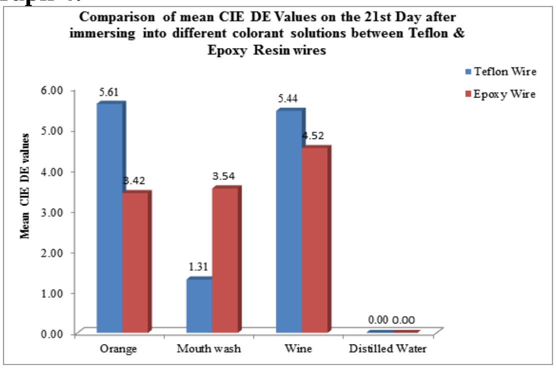


After doing ANOVA and Tukey's Post Hoc test showed stastistically significant color change in all the three colorants when compared to the base values with P value <0.001.

Graph 3:



Graph 4:

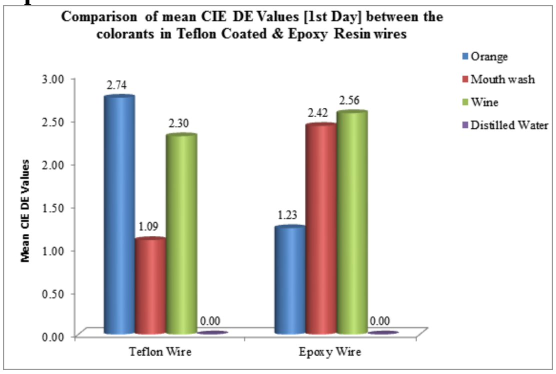


Graph 3 and 4 showed comparision between the two wires, teflon and epoxy after 1st and 21st days of retrieval showing that in Artificial orange and Red wine, teflon showed more color change than epoxy resin coated wire whereas in colgate plax mouthwash epoxy resin coated wire showed more color change than teflon, which was even in statistical report not significant.

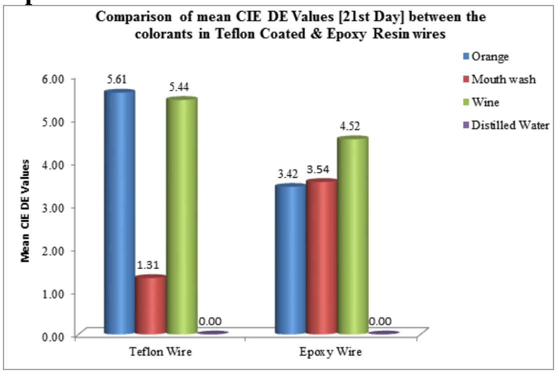
Graph 5 & 6 was obtained to show the effect of each coloring food materials on both the wires i.e. teflon coated and epoxy resin coated ones, which showed that both on 1st and 21st day teflon got maximum discolored by artificial orange then with wine and least with mouthwash, whereas Epoxy got maximum discoloured with wine then to mouthwash and least with artificial orange

Concluding with the result, teflon coated archwires from 1st day have shown color change in all the 3 solutions and which was more in artificial orange and red wine compared to epoxy resin coated wires and consistently this change remained same even on 21st day. Whereas, epoxy resin coated showed maximum discoloration with mouthwash as compared to teflon coated archwires on 1st day and even consistently more discoloration on 21st day of retrieval from the solution.

Graph 5:



Graph 6:



Statistical Methods: Descriptive and inferential statistical analysis has been carried out in the present study. Results on continuous measurements are presented on Mean SD (Min-Max) and results on

categorical measurements are presented in Number (%). Significance is assessed at 5 % level of significance.
The following assumptions on data is made,
Assumptions: Dependent variables should be normally distributed.

Student t test both paired and unpaired (two tailed, dependent) both has been used to find the significance of study parameters on continuous scale with in each group.

Along with that ANOVA and Tukey's Post Hoc test were performed.

Statistical Analysis: The study data was analyzed using SPSS [Statistical Package for Social Sciences] software V.22, IBM., Corp. SAS 9.2, SPSS 15.0, Stata 10.1, MedCalc 9.0.1, Systat 12.0 and R environment ver.2.11.1 were used for the analysis of the data and Microsoft word and Excel have been used to generate graphs, tables.
Descriptive Statistics: The frequency distribution for the study variables, was expressed in terms of Mean & SD, Min & Max.
Inferential Statistics: Student unpaired t test was used to compare the mean CIE DE values between teflon coated & epoxy Resin wires wrt different colorants on 1st & 21st Day.
Student Paired t test was used to compare the mean CIE DE values between 1st & 21st Day for different colorants wrt teflon coated & epoxy Resin wires.
One-way ANOVA followed by Tukey's Post hoc Analysis was used to compare the Mean CIE DE values between Colorants wrt teflon coated & epoxy Resin wires on 1st & 21st Day of evaluation.
The level of significance [P-Value] was set at $P<0.05$

Discussion

To increase the esthetics of orthodontic appliances, metallic archwires are coated with tooth colored resin materials, such as synthetic fluorine containing resin or epoxy resin composed mainly of poly-tetra-fluoro-ethylene. Ideally, the color of esthetic archwires should match that of natural teeth and esthetic brackets. Although it has been found that 25% of coating is lost in 33 days intra-orally and the wire becomes aesthetically degraded. Coating improves esthetics but has some disadvantages, the color tends to change with time and there are internal and external causes for the discoloration of esthetic archwires.[5]

Orthodontic treatment aims to provide individuals with an esthetically pleasing smile, Patients have become increasingly demanding regarding the use of more esthetically pleasing appliances during treatment.[12] This study is done to evaluate the color stability of the various teflon coated and epoxy resin coated esthetic archwires. It was the goal of this research to analyze how certain products and beverages effect the color stability of the esthetic coated wires.

In addition to the color differences initially observed between the different existing esthetic archwires, the color stability of coated archwires during orthodontic treatment is also clinically important. In the current study, the color stability of these archwires could be reliably evaluated. Ideally, the color of esthetic archwires should match that of natural teeth and esthetic brackets. However, the colors of natural teeth vary according to the color measurement protocols used and also by race, gender, and age.[2]

Arthur et al.[20] suggested that changes in the optical properties within a polymer could be responsible for the color changes seen clinically. They stated that chemical discoloration was caused by the oxidation of unreacted double bonds in the matrix of the polymer and the subsequent formation of degradation products from water diffusion or the oxidation of the polymer. This could explain the staining behavior of coated archwires over time.

Some studies[5,12,18,] conducted on ceramic brackets concluded that wine was the most chromogenic agent in comparison with other staining substances, such as mouthwash and cola drinks. For this reason, a wine and mouthwash along with aerated drink (artificial orange) solution was used in this study to evaluate the effect of staining of esthetic coated archwires.

A study[8] stated that mouth washes are widely used during orthodontic treatment as antiseptic agent. All types of mouth wash cause staining. Present study was done to check the effect of mouth wash on color stability of coated archwires.

Another study[9] conducted on color stability of orthodontic clear ligatures stated that, daily exposure to a red wine staining agent significantly increased the ligature color variability. Color variation due to red wine exposure results primarily from impregnation of the elastomeric material by dark pigments. The storage conditions also impact the staining susceptibility. The low pH of red wine and the presence of ethanol may additionally contribute to pigmentation because they impose chemical challenges to the ligature material and potentially make the ligature surface more prone to pigment absorption.

A study[11] conducted on color stability of orthodontic clear ligatures stated that all the solutions altered the final aspect and color of the test specimens in which wine did the most, followed by tea and coca cola the least. These results become important since adult patients are extremely critical about esthetics of the orthodontic appliance and they are frequent consumers of red wine, coffee and tea. Red wine, in turn, showed a great staining effect on resin restorations in another study.[22] This reaction is catalyzed by substances with low pH such as Coca-Cola®, black tea, red wine and coffee. These substances can penetrate into the polymer structure, altering its color and also different brands of these coloring agents may present various effects, on the coloring degree of each one of them.

In the present study, the color changes of teflon and epoxy resin coated archwires intensified with a longer immersion period, wires showed a significant color change between 1st and 21st days. When NBS values were evaluated after the 3-week immersion period, 'marked changes were observed in both the wire groups.

Teflon coated archwires from 1st day have shown color change in all the 3 solutions and which was more in artificial orange and red wine compared to epoxy resin coated wires and consistently this change remained same even on 21st day. Whereas, epoxy resin coated showed maximum discoloration with mouthwash as compared to teflon coated archwires on 1st day and even consistently more discoloration on 21st day of retrieval from the solution. Both the wires showed no color change in control group (distilled water).

According to a study[5] done previously on color stability of different esthetic archwires, there are differences in the amount of color change of the different aesthetic archwires from different companies under the same circumstances; this may be related to the chemical and physical composition of the aesthetic archwires which need further investigations from each company to discover the cause of this variation.

A study done[4] stated that the low pH and high concentration of alcohol tend to increase the potential for staining of certain products. This study showed that the factor most responsible for color changes in the brackets was the amount and type of pigment in the solution, which is in agreement with previous studies showing that color change of bracket was dependent on the solution, storage time and the brand of brackets. Among the different colorants used red wine discolored the most followed by mouthwash.

According to the results the following Interpretations is done: Among the t
eflon coated esthetic archwires the ΔE value for Artificial orange (aerated drink) (5.61±0.30) was highest indicating that artificial orange discolored the wires most in the inter group followed by the red wine (5.44±0.25), and colgate plax mouthwash (1.31±0.15) the least. The difference in the mean ΔE value was found to be statically significant (<0.001**)

Among the epoxy resin coated esthetic archwires the ΔE value for red wine (4.52±0.30) was highest indicating that wires in the red wine discolored most. The colgate plax mouthwash (3.54±0.15) and the artificial orange (3.42±0.14) almost stain same. The difference in the mean ΔE value was found to be statically significant (<0.001**)

The goal of this study was to determine which substances stained the most, and which wires would offer the greatest resistance to color change. The wires were exposed to the staining agents for 21 days, producing significant colour changes in all experimental groups. However, it must be remembered that the wires used in this study were subjected to a far more controlled environment than would exist in vivo.

When we compare the intra group wires of teflon coated and epoxy resin coated, the mean ΔE value was statistically significant in all the experimental groups. But the epoxy resin coated esthetic archwires were less stained as compare to teflon coated wires.

It should also be noted that the wires in this study were of different shapes and sizes, which certainly may be a factor. The geometry, especially thickness of coatings can affect color and any noted changes. The standards for colour measurement were recorded on flat and opaque materials which present many problems when assessing color in dentistry, this affected their definitive esthetic appearance. The differences in thickness between wire brands and within the wires themselves may also have an impact on the colour measurements[5], stated that the mean ΔE* values for two dental systems increased as the thicknesses increased.

According to this study, 2 brands of esthetic coated wires were exposed to artificial orange, mouthwash, red wine and measured color differences with a spectrophotometer. The goal of this study was to determine which substances stained the most, how much time was required for stain to occur and which wire would offer the greatest resistance to colour change. The wires were exposed to the staining agents for either 24 or 72 hours, producing significant colour changes in all exposure groups. The susceptibility of wires to stain is brand dependent and secondly, that even mild exposure to staining agents is sufficient to cause visually significant stain.

It is intriguing to discuss the results of the individual wire types. All wire types in study groups showed a varied degree of color change, noted in their ΔE results. The results of this study have provided insight into a relatively unevaluated area of research in orthodontics and certainly offer beneficial information for practicing clinicians. To obtain a better clinical picture of the color changes of the wires future research should be explore the effect of tooth brushing on their stain resistance.

The findings of this research prove the stated hypothesis that both esthetic archwires will have their optical properties altered according to increased consumption of various staining agents, in vitro.

Limitations: One of the drawbacks of this study as with all in- vitro experiments is the difficulty in accurately reproducing the conditions of the oral cavity, especially temperature. Many efforts were made in the attempt to produce a natural oral environment, but it is a far more complex environment than one produced in a laboratory.

An in vivo study would be ideal; however it adds many confounding variables including variation in diet, oral hygiene, mastication, amount and composition of saliva. The differences in thickness between wire brands and within the wires themselves may have also had an impact on the colour measurements. The highly reflective surface of the wires may have affected our results despite our approach to avoid this bias.

Scope of the Study: To obtain a better clinical picture of the color changes of the wires future research should be done to explore the effect of tooth brushing on their stain resistance.

Conclusion

Esthetic coated archwires will discolor from staining beverages during their lifespan. In esthetically critical area, discoloration of wires for fixed orthodontics might cause patient dissatisfaction. The patient's oral hygiene is an important factor for preventing color changes of the wires.

In the present study the epoxy resin coated archwires were more color stable than the teflon coated wires. The wires in the red wine solution stained the most, whereas wires immersed in the artificial orange and mouthwash shows less discoloration as compared to the wine solution.

The overall result of the study shows epoxy resin coated archwires are more advisable to patients for their color stability.

In this in-vitro investigation, maximum exposure time of 21 days was chosen. Inspite of this short exposure period, almost all investigated esthetics wires showed undesirable discoloration.

Nevertheless, it should be remembered that this was an in-vitro study, and care should be taken in interpreting the results to those that might occur in the oral cavity.

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