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Color Stability Of Ceramic Brackets Immersed In Artificial Saliva And A Potentially Staining Health Drink Solution - An Invitro Study

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ABSTRACT

Objective: The aim of the invitro study was to analyze the color stability of monocrystalline and polycrystalline ceramic brackets after immersion in artificial saliva and a potentially staining health drink solution.

Methods: Twenty monocrystalline and twenty polycrystalline ceramic brackets of American orthodontics were immersed in artificial saliva and health drink solution intermittently for 15 months, respectively. Color changes were measured by a spectrophotometer and visual assessment scale at 0, 3,6,9,12,15 months. Statistical analyses were performed with IBM SPSS version 17. Data were assessed by Multivariate Profile Analysis, Analysis of Variance (ANOVA), and Multiple Comparison Tests of means.

Results: The results from the spectrophotometer and visual assessment show that the polycrystalline ceramic brackets showed a greater degree of stain uptake when immersed in a nutritive health drink solution and the monocrystalline ceramic brackets showed less staining at the end of 15 months.

Conclusion: Both the monocrystalline and polycrystalline ceramic brackets undergo staining when placed in staining solutions. Comparatively monocrystalline ceramic brackets produced less stain and were better than the polycrystalline ceramic brackets when immersed in a health drink solution by 25%. The combined effect of time, type of bracket, and type of staining solution had influenced the degree of stain uptake.

Keywords: Ceramic Brackets, Color Stability, Artificial Saliva, Staining Solution, U-V Spectrophotometer, Visual Assessment.

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INTRODUCTION

Webster has defined the term esthetics as “appreciative of, responsive to, or zealous about the beautiful” [24]. The esthetic demand is not only after the orthodontic therapy but even during the course of treatment. This has resulted in the development of ceramic brackets which were introduced in 1980. There are two types of ceramic brackets based on the manufacturing process. They are the monocrystalline and polycrystalline ceramic brackets. Monocrystalline ceramic brackets have a clear appearance because of the larger grain size and reduced impurities, whereas the polycrystalline brackets tend to reflect light which causes some degree of opacity due to the presence of more impurities during the manufacturing process [34,29]. Thedrawback of ceramic brackets is that they are stained by various food solutions such as tea, coffee, drinks, wine when exposed to the oral environment.

Discoloration of the ceramic brackets generally occurs by two factors – intrinsic and extrinsic factors [1, 2].

1. Intrinsic factors such as water absorption, the composition of the bracket matrix.

2. Extrinsic factors such as pigments present in food, beverages, tea, coffee, wine, mouth rinses.

Olivera et al [7], Faltermeier et al [2] and Yadav et al [26] had used red wine, coffee, tea, coke, and artificial saliva as the staining solutions in their studies. Nutritive health drink powder solution (Boost) is taken as a staining solution for the present study. Artificial saliva has been used to imitate the oral environment because it responds to the sample material in the same way as the natural saliva does. Artificial saliva as a medium has been used in several studies by Olivera et al. The artificial saliva which is used in the study is made by B.N laboratory, Mangalore.

Olivera et al, Faltermeier et al, and Yadav et al conducted the studies to determine the color changes of the ceramic brackets immersed in food solutions for only a short period of one month [26, 7, and 2]. The duration of orthodontic treatment timingis about 15 months. The duration of this study is about 15 months and is not carried out in any of the previous studies.

Investigating the color changes can be determined by anyone of these methods; spectrophotometer, colorimeters, digital photographic analysis, and visual assessment. Spectrophotometer analysis is an effective method for evaluating the color changes and used in several studies done by Lee et al, Olivera et al, Faltermeier et al and Yadav et al. A double beam spectrophotometer is used in this study, wherein a beam of light is allowed to pass through the object and the color of the object is assessed in terms of light transmittance [26, 7, and 2]. Here color changes of the ceramic brackets of two different crystalline structures are determined. When there is a higher demand for esthetics and the patient prefers the ceramic brackets, they expect the brackets to appear esthetically on direct vision throughout the procedure. A study conducted by Olivera et al used the visual assessment scale to determine the color changes of ceramic brackets on direct vision suggested by Mancuso et al varying from +5 to -5 [7, 8].

The purpose of the study is to evaluate the color stability of the monocrystalline and polycrystalline ceramic brackets immersed in artificial saliva and nutritive health drink powder solution for duration of 15 months by UV spectrophotometer and visual assessment scale.

MATERIAL AND METHODS

GROUPING OF SAMPLES:

Forty ceramic brackets manufactured by American orthodontics were chosen for the study. Out of which, twenty were monocrystalline ceramic brackets (Radiance brand) and the other twenty were polycrystalline ceramic brackets (20/40 brand).

The ceramic brackets were divided into two groups:

1. Group A consists of 10 monocrystalline and 10 polycrystalline ceramic brackets.

2. Group B consists of 10 monocrystalline and 10 polycrystalline ceramic brackets.

Group A was sub-grouped as M1 and P1 each consisting of 10 monocrystalline (AM1) and 10 polycrystalline (AP1) ceramic brackets.

Group B was sub-grouped as M2 and P2 each consisting of 10 monocrystalline (BM2) and 10 polycrystalline (BP2) ceramic brackets.

PROCEDURE FOR THE STUDY:

Four Petri-plates (Borosil) containing the artificial saliva (made by B.N.Laboratory, Mangalore) were taken for the study. Among the four Petri-plates, two were placed under group A (control group) and two Petri-plates were placed under group B (experiment group). In group A, the ceramic brackets consisting of subgroups M1 and P1 were immersed separately in 2 Petri-plates with artificial saliva continuously for a period of 15 months. In the group B, the ceramic brackets comprising of subgroups M2 and P2 were immersed separately in 2 Petri-plates with artificial saliva solution and intermittently placed in health drink powder solution (1/2 teaspoon of boost/50 ml of water) for 10 minutes every day and returned back to artificial saliva for a period of 15 months. The entire setup was placed inside the refrigerator maintaining 4-8 degrees Celsius regulated by a thermometer (Legacy pro 6). Once in a month, the saliva was changed and the pH of the saliva was maintained and checked using a litmus paper.

EVALUATION OF CERAMIC BRACKETS:

A total of 10 brackets were available in each of the four subgroups (AM1, AP1, BM2, and BP2). Two brackets (S1 and S2) of monocrystalline and polycrystalline were chosen randomly from group A and group B for the evaluation of color change by using a spectrophotometer and visual assessment scale.

SPECTROPHOTOMETER ASSESSMENT:

The ceramic brackets were evaluated periodically at 0, 3, 6, 9, 12, 15 months using Spectrophotometer (UV−Vis−NIR Spectrometer Perkin Elmer Lambda 19) to assess the color change in the ceramic brackets periodically and the values were given as T0 (before immersion), T1 (3 months), T2 (6 months), T3 (9 months), T4 (12 months), T5 (15 months).

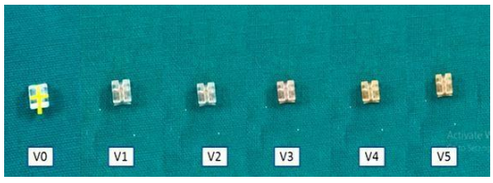
A double beam Spectrophotometer device consists of the light source (Deuterium UV, Tungsten−Halogen Vis/NIR) of wavelength 200 to 2500nm for reflectance which was passed through a collimator. This collimated beam enters the diffraction grating (i.e, prism) and is converted into a spectrum of different wavelengths. A slit was present which allowed a beam of a particular wavelength to pass through the same. The amount of light transmitted through the sample was obtained. The digital reading was recorded as T0, T1, T2, T3, T4, and T5. The initial value T0 was recorded by spectrophotometer before immersion and followed by visual assessment, the brackets were immersed in the artificial saliva solution. The sequence was repeated for every 3 months and the spectrophotometer

values for the brackets in group A and group B were recorded as T1, T2, T3, T4, T5 after immersion. The values obtained from the spectrophotometer were tabulated in Armstrong (Å) units.

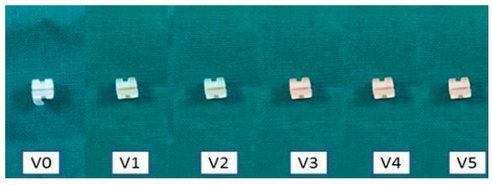
VISUAL ASSESSMENT

Before immersion in the artificial saliva, visual assessment for the same brackets (S1, S2) of group A and group B was done by 2 operators using the Visual assessment scale as suggested by Mancuso et al [8]. Mancuso et al standardized the visual assessment scale with values varying from 5 to +5. The initial value was recorded according to the visual assessment scale before immersion and returned back to the artificial saliva. The sequence was repeated every 3 months and the visual assessment values of the ceramic brackets in group A and group B were recorded after immersion. Inter operator variability was also assessed. The visual assessment values given by operator 1 and operator 2 were tabulated.

Figure-1- UV−Vis−NIR spectrophotometer

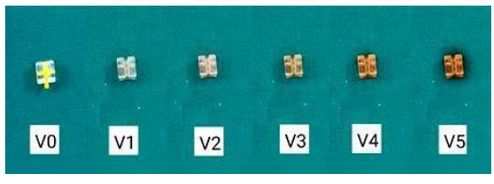


Polycrystalline brackets

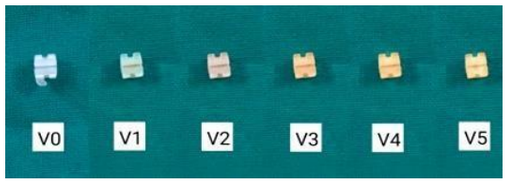


Monocrystalline Brackets

Artificial saliva and health drink powder solution



Polycrystalline brackets



Monocrystalline Brackets

STATISTICAL ANALYSIS

Statistical analyses were performed with IBM SPSS version 17(SPSS Inc., Chicago, IL). Descriptive statistics were computed. The data was found to be in normal distribution using the Shapiro Wilks test.

One way Analysis of Variance (ANOVA) was carried out to analyze significant differences in color changes in terms of mean light transmission between the four subgroups at different time intervals. These analyses were preceded by a test of homogeneity of variances. Hence homogeneity of variances was violated; ANOVA was replaced by Brown-Forsythe test. Post hoc Tamhane's test is used to determine the significance between the four subgroups by multiple comparisons in pairs.

Repeated measures Multivariate Analysis of variance (RMANOVA), and Pillai Trace test were used to evaluate the influence of one or more variables on the degree of staining. Pillai trace test is used as a test statistic in RMANOVA which is a positively valued statistic ranging from 0 to 1. Significance was set as $p < 0.05$.

RESULTS

SPECTROPHOTOMETER ASSESSMENT:

The mean values obtained from the spectrophotometer were in terms of light transmittance. As the staining of the ceramic brackets increases, the light transmittance decreases. The mean values were evaluated by one way ANOVA and Brown Forsythe test; the results were tabulated in Table 1. This shows the comparison of mean light transmission between the four subgroups at different time intervals.

From Table 1, it was found that the significant differences in the color changes were seen in all the time periods (T1-T5) and it was statistically significant except for the baseline values (T0).On comparing the mean values between the four subgroups, the mean value of the polycrystalline ceramic brackets was about 3.03 and the monocrystalline ceramic brackets were about 3.90 at the end of 15 months when placed in the staining solution. The mean value of polycrystalline ceramic brackets was about 4.39 and the monocrystalline ceramic brackets were about 4.51 at the end of 15 months when placed in artificial saliva. This shows that the polycrystalline brackets produced greater staining and showed less light

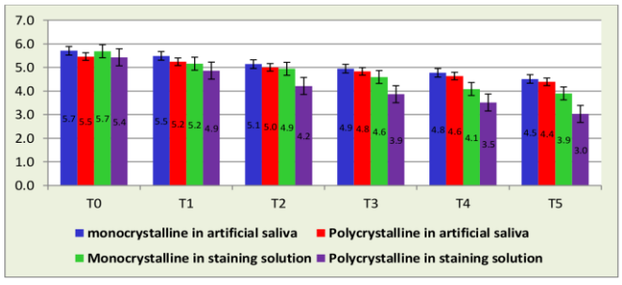
transmittance which was statistically significant (p =0.001) whereas monocrystalline brackets had less stain uptake and more light transmittance in all time intervals.

TABLE 1: Comparison of mean light transmission between 4 subgroups at different time intervals

	Artificial saliva		Staining solution		
	Monocrystalline	**Polycrystalline**	**Monocrystalline**	**Polycrystalline**	**P-value**
T0[a]	5.70 ± 0.06	5.46 ± 0.04	5.68 ± 0.03	5.42 ± 0.04	0.076
T1	5.48 ± 0.06	5.24 ± 0.07	5.15 ± 0.05	4.86 ± 0.06	0.001*
T2	5.14 ± 0.06	5.00 ± 0.06	4.94 ± 0.03	4.21 ± 0.05	0.001*
T3 [a]	4.94 ± 0.03	4.83 ± 0.11	4.59 ± 0.05	3.86 ± 0.04	0.001*
T4 [a]	4.77 ± 0.05	4.63 ± 0.10	4.08 ± 0.05	3.51 ± 0.04	0.001*
T5 [a]	4.51 ± 0.04	4.39 ± 0.11	3.9 ± 0.03	3.03 ± 0.06	0.001*

One way ANOVA test; * shows (p<0.05). Notes: 1) In times marked with a variance are not equal. In this case, ANOVA was replaced by the Brown-Forsythe test.

Graph 1 represents the comparison of mean light transmission between groups at different intervals. There is an overall decrease in the mean light transmission of the ceramic brackets over a period of time in all groups which means that there is a gradual increase in the degree of stain uptake from T0 to T5. At T0, the mean values of monocrystalline ceramic brackets before immersion in both solutions showed similar values and the same with the polycrystalline ceramic brackets have been observed. At the time of T1, T2, T3, T4, and T5, among the four subgroups, the polycrystalline ceramic brackets immersed in staining solution showed the maximum stain uptake with decreased light transmittance. The monocrystalline in artificial saliva showed less stain uptake with increased light transmittance.



GRAPH 1:Comparison of mean light transmission between 4 subgroups at different time intervals.

From Graph 1 and Graph 2, the monocrystalline ceramic brackets immersed in the staining solution do not show much of color change at T1, T2, and T3. The maximum color uptake was seen in T4 and T5 on exposure to staining solution. The polycrystalline ceramic brackets do not show much of color change at T1 whereas there was a significant color change at the time T2, T3, T4, and T5 on exposure to staining solution. significant color change at the time T2, T3, T4, and T5 on exposure to staining solution.

On comparing both the Graphs, at the time of T2, T3, T4, and T5 the color uptake of the polycrystalline ceramic brackets was greater than the monocrystalline ceramic brackets immersed in staining solution. This shows the influence of time on the degree of staining in the brackets.

GRAPH 2: Comparison of mean light transmission based on time trend between monocrystalline.

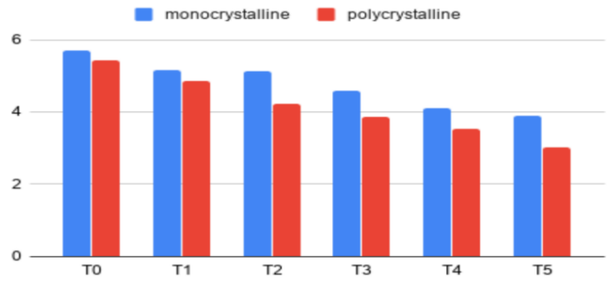


Table 2 showed the pairwise possible comparisons between groups to substantiate in which group such differences were resulted using the Post hoc Tamhane's test. It was found that there was no significant difference in color alteration of similar brackets before the immersion in different solutions at baseline (T0) but significant color changes occurred after immersion of brackets in the staining solution. The mean difference between the monocrystalline and polycrystalline ceramic brackets placed in the staining solution was about 0.258 at T0 (before immersion). At the end of 15 months (T5), the polycrystalline ceramic brackets showed a greater mean difference of 0.870 when compared with monocrystalline ceramic brackets which were statistically significant.

Comparatively polycrystalline brackets showed more color alteration from T1 to T5. The brackets immersed in the health drink staining solution also showed more color change from T1 to T5. This explains the effect of the crystalline structure of the ceramic brackets and the type of staining solution on the degree of stain uptake.

TABLE.2: Post hoc pairwise multiple comparisons of mean light transmission between groups.

Time	(I) grp	(J) grp	Mean difference (I-J)	Std error	p-value
T0	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.24300*	0.02	0.001*
		Monocrystalline in staining solution	0.02	0.02	0.876
		Polycrystalline in staining solution	.27500*	0.02	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	-.22600*	0.02	0.001*
		Polycrystalline in staining solution	0.03	0.02	0.50
	Monocrystalline in staining solution	Polycrystalline in staining solution	.25800*	0.02	0.001*
T1	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.24900*	0.03	0.001*
		Monocrystalline in staining solution	.33100*	0.03	0.001*
		Polycrystalline in staining solution	.62400*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.08200*	0.03	0.029*
		Polycrystalline in staining solution	.37500*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.29300*	0.03	0.001*
T2	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.13800*	0.03	0.001*
		Monocrystalline in staining solution solution	.20000*	0.03	0.001*
		Polycrystalline in staining solution	.92600*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	0.06	0.03	0.081
		Polycrystalline in staining solution	.78800*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.72600*	0.03	0.001*
T3	Monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.11700*	0.03	0.004*
		Monocrystalline in staining solution	.35500*	0.03	0.001*
		Polycrystalline in staining solution	1.08300*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.23800*	0.03	0.001*
		Polycrystalline in staining solution	.96600*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.72800*	0.03	0.001*
T4	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.14000*	0.03	0.001*
		Monocrystalline in staining solution	.68800*	0.03	0.001*
		Polycrystalline in staining solution	1.25900*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.54800*	0.03	0.001*
		Polycrystalline in staining solution	1.11900*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.57100*	0.03	0.001*
T5	monocrystalline in artificial saliva	Polycrystalline in artificial saliva	.12000*	0.03	0.005*
		Monocrystalline in staining solution	.61100*	0.03	0.001*
		Polycrystalline in staining solution	1.48100*	0.03	0.001*
	Polycrystalline in artificial saliva	Monocrystalline in staining solution	.49100*	0.03	0.001*
		Polycrystalline in staining solution	1.36100*	0.03	0.001*
	Monocrystalline in staining solution	Polycrystalline in staining solution	.87000*	0.03	0.001*

Table 3 represents the descriptive statistics in which “a word” is given to represent the summarized data. Three factors were considered as descriptive statistics:

1.Bracket
2.Solution
3.Time

Effect		Mean	Std. Error
Bracket	Monocrystalline	4.911	0.009
	Polycrystalline	4.54	0.009
Solution	Artificial saliva	5.011	0.009
	Standard solution	4.44	0.009
Time	T0	5.57	0.008
	T1	5.188	0.01
	T2	4.825	0.009
	T3	4.56	0.011
	T4	4.252	0.011
	T5	3.958	0.012

The mean values were summarized under each factor and Repeated measures of Multivariate analysis (RMANOVA) were carried out.

Table 4 represents the degree of color change and how multivariate analysis is effective in explaining the variance of outcome variables. The results of RMANOVA and Pillai trace method which shows the effect of time, bracket, and the staining solution on the color change.

Considering the time factor, the observed power value was 1 which means there is a greater effect of the time factor on the stain uptake which means that the stain uptake had increased between the time periods. On combining two factors the time and type of brackets, the power observed was 1 and showed polycrystalline brackets had more color alteration over a time period. Similarly for the other two factors time and type of staining solution, the power observed was 1 and shows the greater effect on the color change shows that staining solution produced more color changes over a period of time.

Similarly, in combined Time * brackets * solution effect, polycrystalline brackets in staining solution showed significantly higher color uptake over a time period. All three factors showed a significant effect on the color change which was statistically significant.

Table 5 describes the effect of 3 combined factors such as time*brackets*solution on the color change which is done by Multivariate analysis. This shows that on exposure to staining solution it led to higher staining patterns on both bracket types at all-time intervals and relatively polycrystalline brackets in staining solution showed a higher degree of staining.

VISUAL ASSESSMENT:

The results of the visual assessment showed that at the end of 15 months, operator 1 observed that the polycrystalline ceramic brackets appeared to be slightly darker than the monocrystalline ceramic brackets when immersed in staining solution based on the visual assessment scale given by Mancuso et al. Operator 2 observed that the polycrystalline ceramic brackets appeared to be darker than the monocrystalline ceramic brackets placed in the staining solution.

From the overall visual assessment readings, it showed that polycrystalline brackets showed more staining than the monocrystalline ceramic brackets on direct observation based on the visual assessment scale. The inter-operator variability was assessed to find out the variations in the readings of the observers and it was about 37%.

DISCUSSION

Many orthodontic patients are concerned about the unaesthetic appearance of the metal brackets and were in need of an alternative. To overcome this problem, the ceramic brackets were introduced in 1980 and are aesthetically accepted by the patients. Based on the manufacturing process, two forms of ceramic brackets are available [22, 9, and 3]. They are monocrystalline and polycrystalline ceramic brackets which were described by Birnie [9], Russell [28], Bishara et al [29]. Even though the ceramic brackets satisfied the esthetic needs of the patient, there was a drawback that these ceramic brackets undergo staining over a period of time.

Axante et al [1] and Faltermier et al [2] reported that the external discoloration of the ceramic brackets is caused by food solutions and mouth rinses. The discoloration of the ceramic brackets can also occur due to internal factors such as composition, structure, and water absorption. Faltermier et al and Arthur et al [2] found that the color changes in the esthetic brackets can be influenced by a number of factors such as type of staining solution, structure and composition of the brackets, oral hygiene, water absorption. In the present study, three factors were considered such as duration of immersion, the crystalline structure of the brackets and the type of staining solution.

The purpose of the present in vitro study was to investigate the color stability of monocrystalline and polycrystalline ceramic brackets immersed in artificial saliva and a potentially staining health drink solution intermittently.

For assessing the color stability of esthetic brackets many authors had used different solutions as a medium for immersion. Filho et al [13] and Kannan et al [18] used common beverages like black tea, coffee and coke. Tangjit et al [23] used yellow curry and green curry; Wried et al [33] used orange juice, red wine and curry; Ismael et al [21] used different plaque solutions as the staining solution. In the present study, a nutritive health drink powder solution has been used as the staining solution as the majority of adolescent patients consume the health drink. Polonczyk et al [27] suggested the use of artificial saliva in the invitro studies in order to simulate the oral environment and was chosen as a medium for immersion in the present study. However, the composition of artificial saliva varies among different manufacturers and does not function in the same way as the natural saliva does [27].

Olivera et al immersed the brackets in the staining solutions for a period of 21days. Faltermier et al [2] investigated the color stability after the immersion for about 72 hours. Kannan et al [18] immersed the brackets for about 6 days. Wried et al [33] evaluated the color changes after 5 days of immersion period. The duration of immersion was found to be less in all the previous studies. Hence the duration of immersion in the present study was taken as 15 months which is the same duration as the orthodontic treatment.

Color changes can be assessed by different methods such as spectrophotometer, colorimeters, digital analysis and visual assessment. Yadav et al [26], Lee et al [37], and Olivera et al [7] used spectrophotometers for the measuring of color changes of the aesthetic brackets. Akyalcin et al [30] analysed the staining of the brackets using digital analysis. Johnston [17] by using the clinical colorimetry and visual assessment evaluated the color stability of the restorations. Mancuso et al used the visual assessment to determine the color stability of facial silicones [8]. Cal et al [6], Jee Ha Choi et al [16], and Stephen J. Chu et al [32] reported that the measurements made from the spectrophotometer and the digital analysis were similar and more accurate than the colorimeter and visual assessment method. Gupta et al considered the spectrophotometer to be a gold standard device for measuring the color changes [10]. Hence, a spectrophotometric method of assessing the color changes has been chosen in the present study.

TABLE 4:Multivariate test for significance of color change for brackets exposed to different staining solutions: time and bracket type factors. Intraindividual factor = time.

Effect	Pillai' Trace	F	df1	df2	p-value	Effect size (Partial Eta Squared)	Observed power
Time	0.998	3.5553	5	32	0.001*	0.998	1
Time * brackets	0.797	25.094	5	32	0.001*	0.797	1
Time * solution	0.981	3.2772	5	32	0.001*	0.981	1
Time* brackets * solution	0.901	58.509	5	32	0.001*	0.901	1

RMANOVA (Pillai trace method) ; * shows (p<0.05)

UV- Vis – NIR Spectrophotometer Perkin Elmer Lambda [19] model has been used for measuring the color changes in terms of light transmittance in the present study. When the light from the device is allowed to pass through the ceramic brackets some of the light gets transmitted which is perceived as the color of the object as described by Smitha in her literature [31]. The spectrophotometric readings were expressed as numerical values. In the present study, a visual assessment scale given by Mancuso et al [8] was used to determine the color changes of the ceramic brackets on direct vision. However Johnston reported that the visual assessment method is not reliable and visual error does occur because of the variations in individual perceptions [17].

TABLE 5: Descriptive statistics for the effect of combined factor (Time* brackets * solution) in Multivariate analysis

Type of brackets	Solution	Time	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Monocrystalline	Artificial saliva	T0	5.70	0.02	5.67	5.74
		T1	5.49	0.02	5.45	5.53
		T2	5.14	0.02	5.11	5.18
		T3	4.95	0.02	4.90	5.00
		T4	4.77	0.02	4.73	4.82
		T5	4.51	0.02	4.46	4.56
	Staining solution	T0	5.69	0.02	5.66	5.72
		T1	5.16	0.02	5.12	5.20
		T2	4.94	0.02	4.91	4.98
		T3	4.59	0.02	4.55	4.64
		T4	4.09	0.02	4.04	4.13
		T5	3.90	0.02	3.85	3.95
Polycrystalline	Artificial saliva	T0	5.46	0.02	5.43	5.49
		T1	5.24	0.02	5.20	5.28
		T2	5.00	0.02	4.97	5.04
		T3	4.83	0.02	4.79	4.88
		T4	4.63	0.02	4.59	4.68
		T5	4.39	0.02	4.34	4.44
	Staining solution	T0	5.43	0.02	5.40	5.46
		T1	4.87	0.02	4.83	4.91
		T2	4.22	0.02	4.18	4.25
		T3	3.87	0.02	3.82	3.91
		T4	3.52	0.02	3.47	3.56
		T5	3.03	0.02	2.98	3.08

In the present study, the color changes in the ceramic brackets were assessed before immersion and after immersion for every 3 months by spectrophotometer and visual assessment scale given by Mancuso et al [8] for a period of 15 months. The visual assessment was done by two operators. The readings obtained from the spectrophotometer and visual assessment were tabulated and the data analysis was done using IBM SPSS version 17(SPSS Inc., Chicago, IL). One way Analysis of Variance (ANOVA) and Multivariate Analysis of variance was done to analyze the differences in color changes in terms of light transmission. Significance was set as $p < 0.05$.In the spectrophotometer assessment, the results of the multivariate analysis showed that both types of ceramic brackets undergo staining gradually in all time periods except for the baseline

value i.e., before immersion. The monocrystalline ceramic brackets showed maximum stain uptake during T4 and T5 whereas the polycrystalline ceramic brackets showed maximum stain uptake during T2, T3, T4 and T5 on exposure with the staining solution. There is a gradual increase in the degree of staining over a period of time for both monocrystalline and polycrystalline ceramic brackets immersed in the staining solution.

Olivera et al [7] and Guignone et al [5] concluded that there was a gradual increase in the stain uptake with an increase in the time of immersion which is in accordance with the present study. This explains how the duration of immersion affects the degree of staining. Tangjit et al [23] reported that both the monocrystalline and polycrystalline ceramic brackets do not follow the same pattern of staining which is in contrast with the present study. From the one way analysis of variance (ANOVA), the polycrystalline type of ceramic brackets placed in staining solution showed greater staining and the monocrystalline ceramic brackets placed in artificial saliva showed the least staining at the end of 15 months. The results from the studies done by Olivera et al [7] and Hussain et al [12] showed that monocrystalline ceramic brackets produced least staining which is in accordance with the present study.

Guignone et al showed that monocrystalline ceramic brackets showed more staining which is in contrast with the present study [5]. Most of the previous studies showed the comparison between different brands of the ceramic brackets and very few studies had compared the two crystalline structures by using the spectrophotometer [7, 12]. Hussian et al and Ismael et al compared the brackets made of different materials such as plastic, composite, monocrystalline, polycrystalline, polycarbonate and zirconium [21,12]. The results of the study showed that the monocrystalline type of ceramic brackets showed least staining which explains that the material of the bracket does influence the stain uptake. This factor was not considered in the present study as the comparison was between two crystalline structures.

The effect of the crystalline structure over the staining of the brackets is explained by Yoshimura et al [39], Jauhar P Mohamed et al [15] and Elliades et al [34]. Based on the manufacturing process the monocrystalline ceramic brackets appear clearer and called translucent brackets which show more light transmittance whereas the polycrystalline ceramic brackets are non-translucent brackets and show limited light transmission [3]. When the ceramic brackets are exposed to staining solution, they undergo discoloration irrespective of the crystalline structure. As the stain uptake of the ceramic brackets increases, the translucency of the material reduces and thus light transmittance is limited [39, 31, 35]. This explains how the crystalline structure does influence the degree of staining and the light transmittance. Lee et al in his study determined that both crystalline structures of ceramic brackets had stain uptake and there is no correlation between the crystalline structure and staining which is in contrast with the present study [37].

Another factor to be considered is the type of staining solution used for the immersion of the ceramic brackets. In the present study, the nutritive health drink powder solution caused a greater degree of staining than the artificial saliva. Few other studies done by Wried et al [33] and Axante et al [1] used sauce, curry, red wine as the staining solution which produced a greater degree of staining. This shows that not only the crystalline structure but also the type of staining solution affect the degree of stain uptake which is in accordance with the present study. The results of the present study showed the combined effect of duration of immersion, type of brackets and the type of the staining solution do influence the degree of staining. There is a gradual increase in the degree of staining over a period of time for both monocrystalline and polycrystalline ceramic brackets immersed in staining solution. At the end of 15 months, monocrystalline ceramic brackets produced less staining and were better than the polycrystalline ceramic brackets by 25%.

From the visual assessment scale given by Mancuso et al, the polycrystalline ceramic brackets placed in the staining solution appeared to be darker than the monocrystalline ceramic brackets reported by 2 operators. Inter Operator variability is about 37%. Even though the visual assessment scale is not a reliable method for evaluating the color change, it can be used along with a standard method like a spectrophotometer.

The present study is of in vitro study and further in vivo studies are needed to evaluate the color stability of ceramic brackets in the oral environment.

CONCLUSION

The results from the spectrophotometer shows that the polycrystalline ceramic brackets showed a greater degree of stain uptake when immersed in a nutritive health drink solution and the monocrystalline ceramic brackets showed less staining at the end of 15 months. There was a significant difference in the color change between the monocrystalline and polycrystalline for all the time intervals except for the baseline reading (T0). There was a gradual increase in the stain uptake for both the brackets placed in the staining solution.

The degree of staining for the monocrystalline was maximum at the time T4 and T5 and for the polycrystalline it was maximum at T2, T3, T4 and T5 from Graph 2 and 3.

The visual assessment scale given by Mancuso et al showed that

polycrystalline ceramic brackets appeared darker than monocrystalline brackets on direct vision. However the visual assessment is not an accurate method for color assessment, but can be used along with thestandard method.

Three factors influenced the degree of staining from the present study:

1. Duration of immersion
2. Type of bracket
3. Type of staining solution

From the present study, it was concluded that both the monocrystalline and polycrystalline ceramic brackets undergo staining when placed in the staining solution. Comparatively monocrystalline ceramic brackets produced less stain and were better than the polycrystalline ceramic brackets about 25%. The combined effect of time, type of bracket and type of staining solution had influenced the degree of stain uptake.

However the present study is in vitro study, further in vivo studies are to be carried out to find the color stability of the ceramic brackets.

BIBLIOGRAPHY

1. Anca Axante, Cristina Teodora Preoteasa, Alexandra Dumitrescu. Color variation assessment of esthetic braces. Romanian Journal of Oral Rehabilitation 2014; 6(4).
2. Andreas Faltermeier, Michael Behr and Dieter Müßig. In vitro colour stability of aesthetic brackets. European Journal of Orthodontics 2007; 29: 354–358.
3. Andreas karamouzos, Athanasios, Moschos Papadapoulas. Clinical characteristics and properties of ceramic brackets. A comprehensive review. Am J Orthod Dentofac Orthop 1997; 112:34-40.
4. Ario Santini, Szu Hui Tiu, Niall J.P. McGuiness & Mohammed Saeed. Light energy attenuation through orthodontic ceramic brackets at different irradiation times. Journal of Orthodontics 2016; 1–9.
5. Bruna Coser Guignone, Ludimila Karsbergen Silva, Rodrigo Villamarim Soares, Emilio Akaki. Color stability of ceramic brackets immersed in potentially staining solutions. Dental Press J Orthod 2015; 20(4).
6. Cal. E, Guneri and Kose. Comparison of digital and spectrophotometric measurements of colour shade guides. Journal of Oral Rehabilitation 2006; (33):221–228.
7. Cibele Braga de Oliveira, Luiz Guilherme Martins Maia and Luiz Gonzaga Gandini Junior. Invitro study of color stability of polycrystalline and monocrystalline ceramic brackets. Dent Press J Orthod 2014.
8. Daniela Nardi Mancuso, Marcelo Coelho Goiato, Stefan Fiuza de Carvalho Dekon, Humberto Gennari-Filho. Visual evaluation of color stability after accelerated aging of pigmented and non pigmented silicones to be used in facial prostheses. Indian J Dent Res 2009; 20(1).
9. David Birnie. Ceramic Brackets. British Journal of Orthodontics. 1990.
10. Gupta.R, Parkash.H, Shah, Jain. A spectrophotometric evaluation of color changes of various tooth colored veneering materials after exposure to commonly consumed beverages. Journal of Indian Prosthodontic Society 2005; 5(2).
11. Hibernon Lopes Filho, Lucio Henrique Maia, Marcus V. Araujo. Colour stability of aesthetic brackets: ceramic and plastic. Aust Orthod J 2013; 29: 13-20.
12. Hussain S. F., Abu Hassan, M. I, Al-Nasir M. Gh. Abdullah N., Abd Latif N. Discoloration of Aesthetic Brackets caused by food dyes: Budu and Chili sauce. Journal of International Dental and Medical Research 2018; 11(1).
13. James C. Ragain. A Review of Color Science in Dentistry: The Process of Color Vision. Journal of Dentistry, Oral Disorders & Therapy 2015.
14. Jane D. Brewer, Alvin Wee, Robert Seghi. Advances in color matching. Dent Clin N Am 2004; (48): 341–358.
15. Jauhar P Mohamed, Pradeep Babu kommi, M Senthil Kumar, Hanumanth, Venkatesan, Aniruddh, Arvinth, Arani Nanda kumar. Evaluating the Type of Light Transmittance in Mono Crystalline, Poly Crystalline and Sapphire Brackets- An Invitro Spectrofluorometer Study. Journal of Clinical and Diagnostic Research. 2016; 10(8): 18-21.
16. Jee-Ha Choi, Ju-Mi Park, Seung-Geun Ahn, Kwang-Yeob Song, Min-Ho Lee, Jae-Youn Jung, Xinyu Wang. Comparative study of visual and instrumental analysis of shade selection. Journal of Wuhan University of Technology-Mater. Sci. 2010.
17. Johnston W. M and E.C. Kao. Assessment of appearance matched by visual observation and clinical colorimetry. J Dent Res 1989; 68(5):819-822.
18. Kannan, Rachana Saboo, Kishore Kumar. Evaluation of colour stability of three polycrystalline ceramic Brackets in three Commonly Consumed beverages An In- vitro

Study. Academic Journal of Oral and Dental Medicine 2014; 1(2): 05-09.

19. Leung V.W.H and Darvell B.W. Artificial saliva for in-vitro studies of dental materials. Journal of Dentistry 1997; 25(6):475-484.

20. Liu Yang, Guangfu Yin, Xiaoming Liao, Xing Yin and Nian song Ye. A novel customized ceramic bracket for esthetic orthodontics: in vitro study. Progress in Orthodontics; 2019: 20(39).

21. Luiza Novelino Acatauassú Ismael, Mauro de Amorim Acatauassú Nunes, Ana Maria Novelino Acatauassú Nunes. Staining of esthetic brackets by plaque disclosing solutions. Braz J Oral Sci. 2014;13(2).

22. Michael L. Swartz. Ceramic brackets. Journal of orthodontics 1988.

23. Nathaphon Tangjit, Kanok-on Tantipanichkul. The color stability of esthetic brackets. M Dent J 2018; 38 (3): 193-204.

24. Patel D, Mehta F, Mehta N. Aesthetic Orthodontics: An Overview. Orthodontic Journal of Nepal 2014; 4(2).

25. Pawan Gautam and Ashima Valiathan. Ceramic Brackets: In search of an ideal. Trends Biomater. Artif. Organs 2007; 20 (2).

26. Puneet Yadav, Pushpa Viney Hazarey, Seema Grover, Maninder Sidhu, Vikas Malik. Evaluation and comparison of color stability of various esthetic brackets, when exposed to various food dyes: An in-vitro study. J Ind Orthod Soc 2013; 47(4): 382-389.

27. J.Pytko-polonczyk, A.Jakubik, A. Przeklasa-Bierowiec, B. Muszynska. Artificial saliva and its use in biological experiments. Journal of physiology and pharmacology 2017; 68(6): 807-813.

28. Russell.J.S. Current Products and Practice Aesthetic Orthodontic Brackets. Journal of orthodontics 2005; 32:146-163.

29. Samir E.Bishara and Dale E Fehr. Ceramic brackets: Something old, something new, A review. Semin Orthod 1997; 3; 178-188.

30. Sercan Akyalcin, Jared Rykiss, Wellington J. Rody and William A. Wiltshire. Digital analysis of staining properties of clear aesthetic brackets. Journal of Orthodontics 2012 ;(39)170–175.

31. Smitha AJ, Savitha PN. Shade Matching in Aesthetic Dentistry – From Past to Recent Advances. Journal of Dentistry and Oral Care Medicine 2017; 3(1).

32. Stephen J. Chu, Richard D. Trushkowsky, Rade D. Paravina. Dental color matching instruments and systems. Review of clinical and research aspects. Journal of dentistry 2010; 38:2-16.

33. Susanne Wriedt, Ulf Schepke, Heiner Wehrbein. The Discoloring Effects of Food on the Color Stability of Esthetic Brackets – an In-vitro Study. J Orofac Orthop 2007; 68.

34. Theodore Elliades, William M. Johnston and Gorge Elliades. Direct light transmittance through ceramic brackets. Am J Orthod Dentofac Orthop 1995; 107:11-19.

35. Vinaya Bhat, Krishna Prasad D, Sonali Sood, Aruna Bhat. Role of colors in prosthodontics: Application of color science in restorative dentistry. Indian Journal of Dental Research 2011; 22(6).

36. Yong-Keun Lee. Aesthetic colour performance of plastic and ceramic brackets - an in vitro study. Journal of Orthodontics 2011, 38:167–174.

37. Yong-Keun Lee. Colour and translucency of tooth-coloured orthodontic brackets. European Journal of Orthodontics 2008; 30: 205–210

38. Yong-Keun Lee. Translucency and color match with a shade guide of esthetic brackets with the aid of a spectroradiometer. Dental Press J Orthod 2016; 21(2).

39. Yoshimura.H.N, Goldenstein.H. Light scattering in polycrystalline alumina with bi-dimensionally large surface grains. Journal of the European Ceramic Society 2009; 29: 293–303.