A spectrophotometric evaluation of color changes of various tooth colored veneering materials after exposure to commonly consumed beverages

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Purpose of study: Proper color match of a dental restoration with the adjacent teeth is important not only at the initial stage of giving the restoration but also over a longer period of time. Out of different materials Porcelain has established itself as being color stable and durable but composites are known to be susceptible to discoloration because of internal mechanisms, external contamination and staining. The newer universal composite systems are optimized in terms of composition to minimize internal discoloration but still not much attention is given to resistance to external staining.

Procedure: Visual shade matching and color determination being a psychophysical phenomenon suffer from subjective variations in interpretation, therefore the present study was undertaken to evaluate and compare the color stability of a porcelain (Vitadur alpha) and two universal composites (Filtek Z 250 and Tetric Ceram) after exposure to commonly consumed beverages i.e. tea, coffee, coca-cola and distilled water (as control) by using a reflectance spectrophotometer and CIELAB system.

Conclusion: The color match of esthetic restorations in the oral cavity is affected by dietary habits

Key Words; Color Stability, Spectrophotometer, CIELAB system

INTRODUCTION

Introduction of laminate veneers in 1970s marked the beginning of modern cosmetic dentistry by combining the principles of esthetics and tooth conservation. Though porcelain veneers have established themselves as ultimate conservative anterior esthetic restorations because of their natural appearance, good wear resistance and color stability. But the composite veneers still take an upper hand in popularity because of several advantages over porcelain such as easier processing and repairing, less time consuming, less expensive and moreover recent improvements in mechanical and handling properties of composites. The newer universal composite systems combine the properties of earlier hybrid composites and micro filled composites. Thus these systems with improved mechanical properties have the advantage of more strength, better translucency and smoother surface finish thus providing an ideal material for veneering purpose. Still one of the properties of the composites that have to pass the test of time is their color stability. Composites are susceptible to discoloration that may be intrinsic or extrinsic.[1,2,3] Intrinsic factors involve discoloration because of alteration of the resin matrix itself or the interface of matrix and fillers, oxidation or hydrolysis in resin matrix.[4,5,6] Extrinsic factors for discoloration include staining by adsorption or absorption of colorants as a result of contamination from various exogenous sources.[7-13] Thus dietary habits such as large consumption of soft drinks and beverages can also contribute to the staining of the laminates.[14] The test commonly applied for determining the color stability of the resinous materials used in dentistry as specified by ADA specification no. 12 and Bureau of Indian Standards IS: 12181-1987 is based on visual comparison of the color of a specimen exposed to the radiation of a Xenon lamp or a radiation source of equivalent energy and then comparing the color of the specimen with the color of an unexposed sample.[15,16]

But these standards do not consider the staining or discoloration caused by food and other exogenous sources in the mouth. Moreover because of the inconsistencies inherent in color perception and specification among observers, only visual comparison is not reliable. Colorimetry, based on comparison with a known standard is the most scientific and practical method to assess color stability.[10]

A Spectrophotometer is scientific standardized colorimetric equipment for matching and measuring colors that gives information about reflectance curve as a function of wavelengths in entire visible range and thus numerically specifies the perceived color of an object. CIELAB (Commission Internationale de I'Eclairage) color coordinates system is a very useful mode that provides information about location of object color in a uniform 3-dimensional color space. It quantifies the color in terms of three coordinate values L*, a*and b*. Here L* represents brightness or lightness (value) and a* and b* serve as numeric correlates both for hue and chroma.[20] The a*and b* values represent position on a red/green and yellow/blue axis, respectively: + a*=red, - a*= green, + b*=yellow and - b*= blue.[17]

The magnitude of the color difference perceived between two objects is calculated by formula $\nabla E = (\nabla L^2 + \nabla b^2 + \nabla a^2)$ ½

MATERIAL AND METHOD

This study was conducted to evaluate the effect of three commonly consumed beverages viz. coffee, tea and coca-cola on color stability of two universal hybrid composites viz. Filtek Z 250 and Tetric-Ceram and an aluminous porcelain i.e. Vitadur alpha. Distilled water was taken as the control. Specimens were prepared in the form of discs. Shade used for test material was A_3 .Twenty discs of each material were prepared with a diameter of 30±1 mm and thickness of 1± 0.1 mm. A three-piece metal mold with specified dimensions was machined and used for making the discs (Figure: 1). To prepare test solution 30gms of coffee powder and 30 grams of tea were added, each into 1 liter of boiling distilled water, both simmered for 5 min. and then filtered through a filter paper. 20 ml of anti-microbial solution was added to each 250 ml of test solution to prevent any microbial growth.

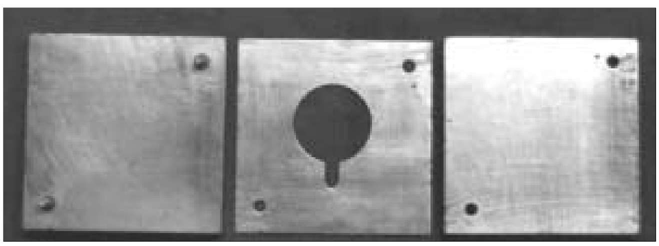

Figure 1: Metal mold

A disc of addition silicone was prepared by injecting the material between the two halves of metal mold and both halves of the mold were pressed uniformly. The silicone disc thus obtained was then placed inside a wax mold and the wax mold was filled with vitadurvest investment material to prepare a mold. Porcelain was applied on the mold, condensed and trimmed flush with the top of the mold and fired. Final glazing was done. The disc was removed from refractory mold taking care not to damage the polished surface.

Composite disc preparation

The same preformed metal mold was used for making the composite discs. A cellophane sheet was placed at the base of the mold and then the material was placed in the mold and pressed uniformly. Extra flash was removed and material was made flush with the top of the mold surface. The specimen disc was light cured from both the sides as instructed by manufacturer using a visible light cure unit. The curing time for Filtek Z 250 was 40 seconds whereas 20 sec for Tetric Ceram. Curing was done at the center and then at 6 positions around the periphery to ensure complete polymerization. The specimens were finished and polished using sof-lex composite finishing and polishing system. Water resistant marker was used to label the specimens on one side.

250 ml of each solution was taken and specimens were immersed in solutions. Coffee, tea and distilled water were kept at a constant temperature of 50 ± 1°C in an incubator. Coca-cola was kept in a closed container in a dark place, at room temperature (20-25°C). Test solutions were changed after every 7^{th} day. Color changes were measured at an interval of 1 day, 15 days and 30 days for all the solutions. The samples in the Coca cola were stored for an extended period of time to rule out any change in reading due to temperature difference and one additional reading was taken at the end of 4 months.

Following removal from the staining solutions, the samples were dipped in distilled water and moved up and down ten times. The samples were then wiped dry with tissue paper and then placed in viewing port for color measurement. "Macbeth Color eye 7000 A" (Reflectance spectrophotometer) was used in the study. The software used was Novascan color matching and analysis software. Color changes were calculated by using the formula:

Change in color $\nabla E = (\nabla L^2 + \nabla b^2 + \nabla a^2)$ ½

Statistical software SPSS 7.5 was used for analyzing the data. One-way ANOVA with multiple range test (Bon-Ferroni Test) was applied to see significant difference among the group. To see the trend or impact of different beverages with in the group, two ways ANOVA with multiple range test (Friedman's test) was applied.

RESULTS

All the three factors studied i.e. type of material, solution and time factor had a significant effect on each of the three measured color parameters. Porcelain after immersion in the test solutions showed a small amount of color change after 1 month that was clinically non-perceptible, in all the solutions including distilled water. The color change ranged from 0.7 ∇E units in water to 1.32 ∇E units in coffee after 1 month (Graph 1). Filtek Z 250 and Tetric-Ceram showed increased discoloration over the observation period of 1 month. Filtek Z 250 showed a color change ranging from 2.34 ∇E units in water to 6.79 ∇E units in coffee after 1 month. The color change in Tetric-Ceram ranged from 2.32 ∇E units in water to 6.57 ∇E units in coffee after 1 month (Graph 2,3).

The difference in total discoloration was significant between porcelain and both the composites ($p < 0.001$), composites showing more discoloration than porcelain in all the solutions. Maximum mean difference between porcelain and Filtek Z 250 was, in water –1.64,in tea –3.64, in coffee –5.47 and in coca-cola –3.3. Maximum mean difference between porcelain and Tetric-Ceram

Color change along individual coordinates of the CIELAB system (Table 1,2,3,4)

Table 1: ANOVA for color changes in different test solutions at different time intervals after exposure to water

	Porcelain			FiltekZ 250			Tetric Ceram		
Water	L	a	b	L	a	b	L	a	b
Base	81.02±0.03	1.29±0.1	9.64±0.03	70.51±0.14	-0.85±0.02	7.65±0.29	69.41±0.05	-0.87±0.01	9.44±-.06
Day 1	80.69±0.09	1.08±0.08	9.54±0.05	69.87±0.16	-1.08±0.04	8.23±0.11	68.48±0.08	-0.97±0.02	9.68±0.03
Day15	80.54±0.06	0.99±0.03	9.46±0.04	68.96±0.22	-1.22±0.08	8.55*±0.13	68.08±0.1	-1.22±0.06	9.88±0.08
1 mon	80.45*±0.03	0.95*±0.01	9.42*±0.04	68.49*±0.08	-1.38*±0.11	8.69*±0.07	67.28*±0.11	-1.38*±0.05	10.19*±0.21
4 mon	-	-	-	-	-	-	-	-	-

* Significant when compared with base line, $p < 0.05$

■ Significant change between two different time intervals, $p < 0.05$

Table 2: ANOVA for color changes in different test solutions at different time intervals after exposure to tea

	Porcelain			FiltekZ 250			Tetric Ceram		
TEA	L	a	b	L	a	b	L	a	b
Base	81.07±0.07	1.27±0.04	9.62±0.02	70.51±0.11	-0.85±0.03	7.69±0.18	69.36±0.08	-0.85±0.02	9.42±0.06
Day 1	80.58±0.08	0.97±0.03	9.39±0.04	68.56±0.15	-0.52±0.03	8.73±0.16	67.43±0.1	-0.4±0.05	10.59±0.08
Day 15	80.41±0.05	0.87±0.03	9.26±0.08	67.43±0.15	-0.12±0.03	9.31±0.07	65.62±0.12	0.9±0.1	11.5±0.11
1 mon	80.24m±0.08	0.74m±0.04	9.19m±0.07	66.48m±0.28	0.13m±0.07	9.92m±0.14	64.72m±0.12	1.21m±0.01	12.14m±0.17
4 mon	-	-	-	-	-	-	-	-	-

* Significant when compared with base line, $p < 0.05$

■ Significant change between two different time intervals, $p < 0.05$

Table 3: ANOVA for color changes in different test solutions at different time intervals after exposure to coffee

	Porcelain			FiltekZ 250			Tetric Ceram		
Coffee	L	a	b	L	a	b	L	a	b
Base	81.1±0.06	1.22±0.05	9.61±0.01	70.55±0.13	-0.84±0.03	7.57±0.19	69.46±0.1	-0.88±0.03	9.43±0.05
Day 1	80.54■±0.04	0.84±0.04	9.4±0.06	68.51±0.29	-0.53±0.04	8.64±0.21	66.59±0.18	-0.3±0.03	11.32±0.08
Day 15	80.14*±0.09	0.69±0.02	9.12±0.07	66.31±0.22	0.27±0.07	9.45±0.25	65.27±0.09	0.55±0.05	12.13±0.14
1 mon	80.08*■±0.08	0.62*±0.02	9.04*±0.06	64.7*±0.11	0.52*±0.03	10.72*±0.19	64.29*±0.16	1.05*±0.11	12.99*±0.13
4 mon	-	-	-	-	-	-	-	-	-

*Significant when compared with base line, $p < 0.05$

■Significant change between two different time intervals, $p < 0.05$

Table 4: ANOVA for color changes in different test solutions at different time intervals after exposure to coca-cola

	Porcelain			FiltekZ 250			Tetric Ceram		
Coca-cola	L	a	b	L	a	b	L	a	b
Base	80.96±0.17	1.28±0.05	9.62±0.03	70.54±0.22	-0.86±0.02	7.62±0.23	69.27±0.13	-0.87±0.03	9.44±0.06■
Day 1	80.78■±0.07	1.02■±0.05	9.25■±0.09	69.24■±0.16	-0.59■±0.09	8.36■±0.26	68.76■±0.09	-0.93■±0.02	8.73±0.06
Day15	80.28±0.14	0.92±0.04	9.15±0.06	68.26±0.09	-0.4±0.08	8.66±0.16	67.52±0.1	-1.0±0.06	8.26±0.08
1 mon	80.14±0.21	0.79*±0.02	9.07*±0.08	67.13*±0.09	-0.17*±0.07	9.16*±0.16	66.83*±0.07	-1.44*±0.07	7.73*±0.05
4 mon	80.1* ±0.14	0.75*±0.02	9.0*■±0.08	66.61*■±0.12	-0.05*■±0.04	9.57*■±0.17	66.5*■±0.04	- 1.62*■±0.07	7.48*■±0.12

* Significant when compared with base line, $p < 0.05$

■ Significant change between two different time intervals, $p < 0.05$

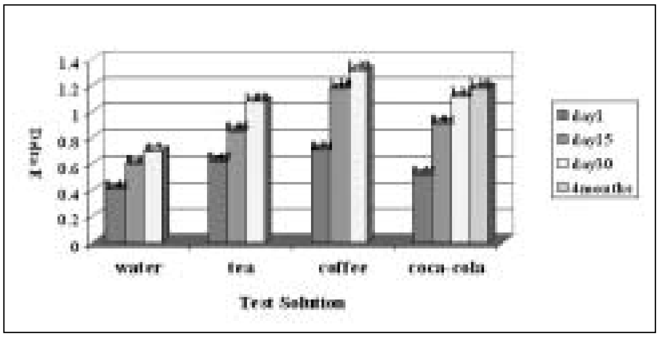

Figure 1 : Total Discoloration of Porcelain in Different Beverages at Different Time Intervals

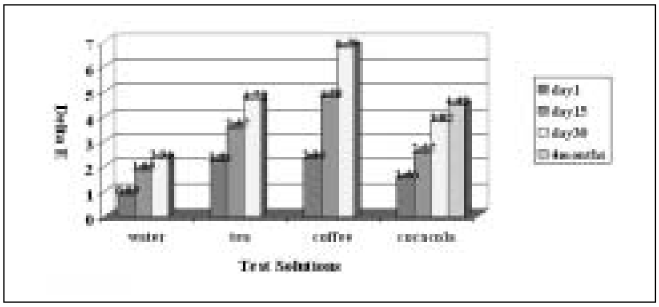

Figure 2 : Total Discoloration of Filtck Z 250 Different Beverages at Different Time Intervals

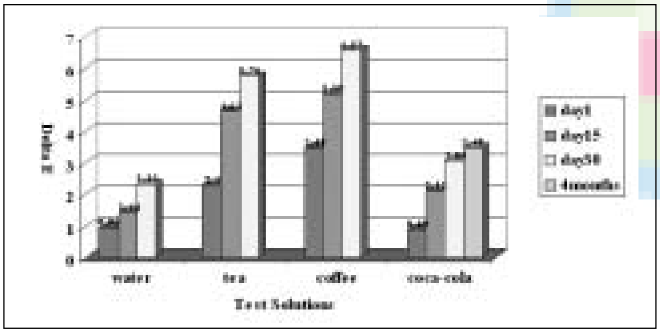

Figure 3 : Total Discoloration of Tetric Ceram in Different Beverages at Different Time Intervals

250 was, in water –1.67,in tea –4.68, in coffee –5.25 and in coca-cola –2.3.

When comparing the composites for total discoloration, it was seen that coffee and water caused more discoloration in Filtek Z 250 than Tetric-Ceram but the difference was not significant. Tea was found to cause significantly more discoloration in Tetric-Ceram whereas coca-cola caused significantly more discoloration in Filtek Z 250.

Considering the mean staining intensity of all the solutions, coffee was found to cause more discoloration than tea, coca-cola and water as is evident by the results which shows that all the test materials including porcelain discolored most in coffee.

There was a significant change in ∇L (brightness) after a period of 1 month. All the materials showed a negative ∇L value (a decrease in L value) i.e. became darker and less bright with time. Porcelain showed a statistically significant change ($p < 0.05$) in water, tea and coffee after 1 month. The change ranged from 0.57 units in water to 1.02 units in coffee. Filtek Z 250 showed change in L value ranging from 2.02 units in water to 5.85 units in coffee. Change in Tetric-Ceram ranged from 2.13 units in water to 5.17 units in coffee. Both the composites showed significant change in L value ($p < 0.05$) after 1 month as well as 4 months when compared with the value at 1st day.

When compared with porcelain there was significantly more change in both composites ($p < 0.001$). When composites were compared with each other, it was found that Tetric-Ceram showed significantly more change than Filtek Z 250 in water and tea ($p < 0.001$) whereas Filtek Z 250 showed significantly more change than Tetric-Ceram in coffee and coca-cola ($p < 0.001$). Maximum change along 'L' coordinate was seen in Filtek Z 250 in coffee. L coordinate showed the maximum change amongst L, a and b coordinates in all the three materials.

∇a (change along red-green axis) was found to be significant for all the three materials after 1 month as well as 4 months ($p < 0.05$) in all the solutions. Porcelain showed negative ∇a therefore indicating a shift towards green color. Filtek Z 250 and Tetric-Ceram showed a positive ∇a value in tea and coffee thus becoming red with time with Tetric-Ceram showing more change in value than Filtek Z 250. In water, both Filtek Z 250 and Tetric-Ceram showed a negative ∇a value thus becoming green with time. Coca-cola was found to cause more greening of Tetric-Ceram but less greening of Filtek Z 250. Maximum change in 'a' coordinate was seen in Tetric-Ceram after exposure to tea. When compared with porcelain there was significantly more change in both composites ($p < 0.001$). The difference between both the composites was significant ($p < 0.001$) in all the test solutions except for water.

The change along 'b' coordinate (change along yellow-blue axis) was found to be more than the change along 'a' (change along red-green axis) coordinate. All the three materials showed a statistically significant change ($p < 0.05$) in all the solutions after 1 month as well as 4 months. Porcelain showed a negative ∇b thus indicating a shift towards blue color or became less yellow. Filtek Z 250 showed a yellowing effect in all the solutions including distilled water. Tetric -Ceram showed yellowing in water, tea and coffee but a shift towards blue in coca-cola.When compared with porcelain there was significantly more change in both composites ($p < 0.001$). The difference between both the composites was significant ($p < 0.001$) in all the test solutions. Yellowing effect was more in Filtek Z 250 after exposure to water and coffee whereas tea caused more yellowing of Tetric –Ceram.

DISCUSSION

A number of factors are known to influence the intrinsic color stability as well as extrinsic stain resistance of the composites. In the present study it was taken care to minimize the different factors that could precipitate the staining of samples during polymerization, finishing and storage. It is evident from the literature that composite surfaces polymerized against mylar surface alone without subsequent polishing, stains more because of inferior physical properties of surface layer.[2, 12,18,19] therefore to avoid incorporation of any such variable, the composite samples in the study were polymerized against mylar surface and then polished with the standard polishing method using sof-lex polishing system as described by the manufacturers.

To simulate the clinical discoloration potential of the composites, the samples were stored at 50°C in accordance with the accelerated lab test given by Asmussen (1983)[20] which stated that the color changes produced in composites by storing for one month at an increased temperature of 50-60°C was well correlated with color change obtained after storing for 12 months at 37°C.

The color measurements in the present study were carried out using a spectrophotometer, as color perception is a psychophysical phenomenon with variations, both between individuals and within an individual at different times and instrumental measurement has the advantage of obviating the subjective errors of color assessment.[16] Tristimulus colorimeters have been found to have precision for in-vitro measurements of color and color differences.[17, 21,22] Therefore Standard Commission Internationale de l'eclairage (CIELAB) color system was used to express the magnitude of color and relative color changes of all the specimens.

Even Porcelain after immersion in the test solutions showed a color change ranging from 0.7 -1.32 ∇E units after 1 month though it was not in a visually perceptible range. The overall color changes were in a range similar to that reported in a study by Razzoog et al (1994) [23] in which two porcelain systems viz. Ceramco and Procera showed a color change in the range of 0.5- 1.5 ∇E units after an accelerated aging process for 900 hours in a weathering chamber. Douglas (2000) [24] evaluated the color stability of various indirect resins (Artglass, Zeta, Targis, Belleglass), one direct resin (Herculite XRV) and porcelain system (Omega 900) after accelerated aging for 300 hours. Porcelain was reported to discolor the least and was not significantly different from Zeta and Artglass that showed a color change in the range of 0.62 - 3.4 ∇E units. But these studies differed from the present study since these studies evaluated only the change that occurred over time (effect of aging) and did not evaluate the resistance against external staining. Considering the mean staining intensity of all the solutions, coffee was found to cause more discoloration than tea, coca-cola and water as is evident by the results which shows that all the test materials including porcelain discolored most in coffee. This is in general agreement with the results of previous studies conducted to find effect of various staining agents on different resinous materials.[8, 22,25] Gross and Moser (1977)[8], and Yannikakis (1998)[22] found that the staining intensity of coffee was higher than tea and water. Chan, Fuller and Hormati (1980)[25] found that coffee caused more discoloration than tea and cola beverages. In contrast a study by Moon, Eystein and Ruyter (1991)[26] on staining of resin based veneering materials with three heat cured and two light cured resins as test materials showed more discoloration by tea in comparison to coffee over an observation period of 48 hours. But at the same time, it reported that staining with tea was superficial and more easily removed in comparison to coffee stains after cleansing treatment with soap and toothbrush. However these results cannot be truly compared with the present study because of different test materials and smaller observation period. Tea was found to cause more discoloration in Tetric-Ceram than Filtek Z 250. This has been explained on the basis of nature of the filler particles present in Tetric-Ceram i.e. glass fillers have been reported to discolor more with tea. This is in agreement with the study previously reported in literature by Gross and Moser (1977)[8] which reported that composite with glass beads as filler (Prestige) stained more with tea.

When the trend for color change was observed over the observation period of 1day to 1 month, it was noticed that Tetric-Ceram showed a greater amount of discoloration in the first two weeks in general, whereas Filtek Z 250 showed a marked increase in discoloration after 15 days, which could be due to inherent intrinsic properties of the composites. The possibility of a slow breakdown at matrix- filler interface because of water sorption and increased temperature cannot be ruled out especially when it is known that the filler particles in Filtek Z 250 are not silane treated (Technical Product profile- Filtek Z 250 by 3M). At the same time Tetric-Ceram contains ytterbiumtrifluoride for fluoride release (Scientific documentation- Tetric-Ceram by Vivadent-Ivoclar). The fact that this component is water-soluble and leaches out after immersion in a solution, might have affected the early color changes in Tetric-Ceram. Another interesting fact about the composition of Tetric-Ceram is that it is based on a catalyst system that contains a stabilizer along with the initiator, in order to decrease the sensitivity to the ambient light sources, by delaying the beginning of the polymerization process.[28] The presence of this component could be responsible for delay in the completion of the

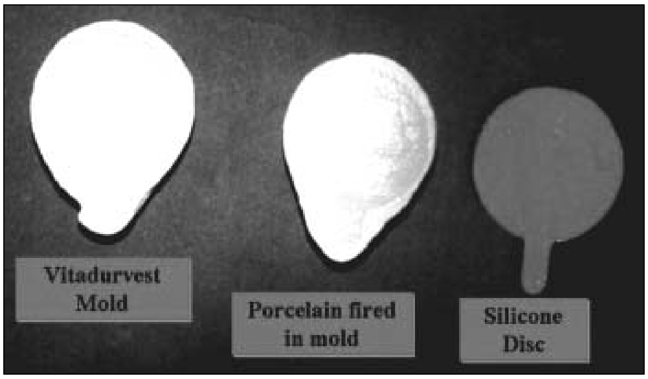

Figure 2: Porcelain disc fabrication

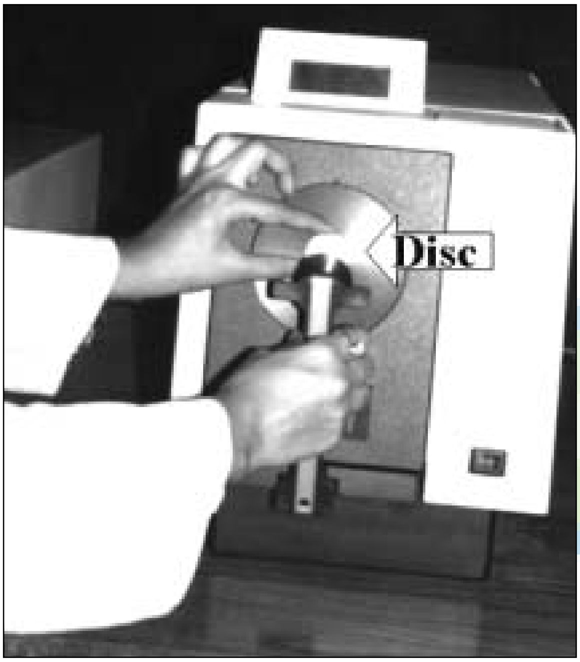

Figure 3: Sample placement

polymerization of the composite and thus resulting in increased intake of fluids in the initial stages of observation period.

These results are in partial agreement with the study by Buchalla (2002)[27] that was conducted to determine the color and translucency changes in a hybrid composite (Tetric) and a microfilled composite (Silux-plus) after exposure to an artificial light with and without water. The samples were stored at room temperature (23°C) for 1month. Both the materials in the study showed negative ∇L value (a decrease in L value) i.e. darkening with time. There was a blue shift (negative ∇b) for both the materials. In the present study, changes along L axis are in agreement with that by Buchalla but changes along b axis are different. The difference could be due to difference in the experimental conditions. In our study, samples were stored at an increased temperature of 50°C to simulate a long-term clinical exposure. Secondly, the test solutions in the present study were tea, coffee and coca-cola along with water as a control. Thus tea and coffee were found to cause yellowing and reddening of the composites and is in agreement with previous studies and has been explained on basis of yellow component present in both the solutions.[10, 26] The response to coca-cola varied among the test materials. The extremely low pH of coca-cola (approx. 2) can be a contributing factor to changes in the color characteristics of the materials. The control i.e. distilled water, was also found to cause small variations in color which may be due to increased temperature, causing increased water uptake by the materials and leaching out of few soluble components of the materials.

Clinical significance

It has been claimed that under clinical conditions in the mouth ∇E color differences have been reported as relevant only when the value is higher than 3.3 or 3.7. Thus the changes in both the composites are of relevance clinically as these changes would be apparent after prolonged and frequent exposure of the restorations to tea, coffee and coca-cola. Thus porcelain can be considered color stable and resistant to external staining. It is difficult to entirely correlate laboratory findings with the clinical behavior of any restoration, since a number of factors are at play in oral environment and therefore to find a correlation between clinical studies and lab measurements, further in-vivo clinical assessment is suggested. From the present in-vitro study, it can be concluded, however, that the color match of esthetic restorations can be maintained over a longer period of time in the oral cavity by observing some restrictions on the dietary habits.

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