ORIGINAL RESEARCH

Effect of Indian Chromatogens on Color Stability of commercially Available Different Tooth Colored Provisional Restorative Materials: An *in vitro* Study

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ABSTRACT

Aim: To compare and evaluate color stability of different types of tooth colored provisional restorative materials in tea, tobacco, and sambhar solution over a period of 1, 2, and 4 weeks.

Statement of problem: The effect of tea, tobacco, and sambhar solution on provisional restorative materials still remains unknown.

Materials and methods: Thirty disk-shaped specimens (20 × 2 ± 0.5 mm) were prepared from heat-polymerized (DPI heat cure), autopolymerized (DPI self-cure) polymethyl methacrylate, and light-polymerized (Revotek LC) resin composite provisional restorative material each, using a circular metal mold. Staining solutions used were tea, tobacco, and sambhar. Artificial saliva was used as control. Specimens were divided into three groups (n = 10) and were evaluated for color change at an interval of 1, 2, and 4 weeks. Color was measured as CIEL*a*b* with a spectrophotometer. Color change (ΔE) was calculated and the data was analyzed with ANOVA and *post hoc* (Tukey) test ($\alpha < 0.05$).

Results: The interactions of provisional restorative materials, staining solutions, and the duration of exposure to the staining solutions were statistically significant. Light-polymerized provisional restorative materials showed the highest change in color after 1, 2, and 4 weeks of immersion in the staining solutions, whereas heat-polymerized provisional restorative materials showed the least change in color. Among the staining solutions, sambhar solution showed the highest staining ability followed by tea, whereas tobacco solution showed the least staining ability.

Conclusion: The heat-polymerized provisional restorative material tested was most color stable and the sambhar solution exhibited the highest staining capacity.

Keywords: Color stability, Provisional restorative materials, Sambhar solution, Tea solution, Tobacco solution.

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INTRODUCTION

Provisional restorations are an essential component of fixed prosthodontic treatment. They provide the clinicians with valuable diagnostic information, act as a functional and esthetic try-in, and serve as a blueprint for the design of the definitive prosthesis. Physical properties, handling properties, patient acceptance, and material cost should be considered while selecting a material for fabrication of a provisional restoration.

Color stability is one of the physical properties that affects the ability of materials to retain their original color. The discoloration of provisional restorations can result in an esthetic problem. This is especially true when more extensive prostheses require provisional restorations for longer interim periods. Discoloration can be affected by several factors including incomplete polymerization,[1,2] water sorption,[3,4] chemical reactivity,[5,6] diet,[7-9] oral hygiene,[10,11] and surface smoothness of the restoration.[12-17] Most materials used for provisional restorations are subject to sorption, a process of absorption and adsorption of liquids depending on environmental conditions.[18] Should a contacting solution be pigmented, discoloration is possible.

The Indian food consists of various components that are chromatogens, such as tea, coffee, colas, turmeric powder, red chilly powder, spices that are cooked in oil, etc. and are consumed on a daily basis and can adversely affect the color of the provisional restorative material. The consumption of tobacco has also increased alarmingly. With high intake of such chromatogens, the color stability of provisional restoration may become questionable.

A number of studies have looked at the color stability of provisional restorative materials in various chromatogens (coffee, tea, colas, cherry juice, mouthrinses, etc.).[8-19] However, the effect of commonly consumed chromatogens by the Indian population on provisional restorative materials still remains unknown.

Therefore, the purpose of this study was to evaluate and compare color stability of commercially available different types of tooth colored provisional restorative materials in tea, tobacco, and sambhar solution over a period of 1, 2, and 4 weeks.

MATERIALS AND METHODS

Three staining solutions (tea, tobacco, and sambhar) were used and their effects on stainability of one heat-polymerized (DPI heat cure), one autopolymerized (DPI self-cure) polymethyl methacrylates, and one light-polymerized resin composite (Revotek LC) were observed. The details of restorative materials and staining solutions used in this study are shown in Table 1.

Tea solution was prepared by adding 5 gm of tea (Society Leaf Tea) with 10 gm sugar and 10 gm milk powder (Nestle EveryDay) in 300 ml of distilled water and boiled for 10 minutes according to the manufacturer's suggested concentration. After boiling, the tea was filtered using filter paper.

Tobacco solution was prepared by soaking 1 sachet, i.e., 8 gm, of tobacco mixed with lime and menthol (Miraj Tobacco) in 300 ml of distilled water for 30 minutes. It was then filtered using filter paper.

Sambhar solution was prepared following manufacturer's instructions using 50 gm of cooked pigeon peas, turmeric, sambhar masala (Everest), salt, and oil. The mixture was boiled for 10 minutes.

The staining solutions were diluted using artificial saliva in the ratio 1:2 by volume.

Thirty disk-shaped specimens 20 mm in diameter and 2 ± 0.5 mm in thickness were prepared from each

Table 1: Materials used

Product	Material type	Manufacturer
DPI heat cure	Heat-polymerized polymethyl methacrylate	Dental Products of India, 9 Wallace Street, Mumbai
DPI self-cure	Autopolymerized polymethyl methacrylate	Dental Products of India, 9 Wallace Street, Mumbai
Revotek LC	Light-polymerized composite resin provisional material	GC Corporation, Tokyo, Japan
Everest sambhar masala	Sambhar masala	S Narendrakumar & Co, Vikhroli (West), Mumbai
Society Leaf Tea	Tea	Amar Tea Private Ltd., Krishnabai Comp., Bhiwandi, Thane-421302.
Miraj Tobacco	Tobacco	Miraj Products Private Ltd., Miraj Campus, Nathdwara-313301, Rajasthan
Artificial saliva	Artificial saliva	MP Sai Enterprise, Mumbai-53

material using a circular metal mold. Specimens for heat-polymerized and autopolymerized polymethyl methacrylate materials were processed in gypsum molds made by investing wax pattern discs in denture flasks. Materials were dispensed, manipulated, and polymerized according to the manufacturer's instructions. For heat-polymerized specimens, the material was packed and processed initially at 74°C for approximately 2 hours and then at 100°C for 1 hour. For autopolymerized specimens, the material was allowed to polymerize initially for 30 minutes and then was left under pressure for a minimum of 3 hours to ensure sufficient polymerization. For light-polymerized specimens, the moldable material was directly placed into a mold placed on a flat glass plate and polymerized using Blue Lex-105 curing unit (Monitex) initially for 10 seconds, followed by 20 seconds with the light tip at a distance of 1 mm from the surface of the specimen. Specimens were kept dry at room temperature until all specimens were fabricated. All specimens upon polymerization were removed from the mold and examined for consistency of the polymerized surface. Specimens were polished by one operator using timed and controlled steps. The polishing media used was coarse pumice powder. Pumice powder and distilled water were mixed to obtain a consistent mix for each specimen. A dental lathe (Rhythm Dental Grinder) operating at 2880 rpm was used for all polishing procedures. The same operator polished all specimens. Specimens were polished on the testing side using a 15-second application of coarse pumice applied with a moist muslin wheel, followed by 90-degree rotation and another 15-second polish. Before the initial color measurement, visual observation of polished surfaces of all specimens was made and presence of any obvious porosity was noted. Specimens were divided into groups of three (n = 10) and were randomly picked and serially numbered with an acrylic bur and the data was recorded accordingly.

For all specimens, artificial saliva was used as control. Specimens were kept immersed in artificial saliva at 37°C for 24 hours, and against this, the color change in the specimens immersed in the staining solutions was recorded. The specimens were immersed in sambhar and tea solutions at a temperature of 50°C and in the tobacco solution at a temperature of 37°C, which are the approximate temperatures at which they can be consumed. The specimens were stored immersed in respective solutions at 37°C in an incubator and evaluated for color change at an interval of 1, 2, and 4 weeks. New solutions were made every day. Before measurements were made, each specimen was rinsed with distilled water for 30 seconds and gently cleaned with a medium bristle toothbrush (Oral-B Medium Toothbrush) to remove any loose sediment resulting from the staining solution.

The specimens were then wiped clean dry using an absorbing tissue paper and thereafter subjected to spectrophotometric analysis. The spectrophotometer used was Color i7™ Benchtop Spectrophotometer (Xrite). This instrument allows color measurement of glossy surfaces, with light provided by a pulsed xenon arc lamp. The specimens were placed with the help of a specimen holder attached to the spectrophotometer. The specimen holder was designed to contain the specimen, fit over the measuring aperture of the spectrophotometer, and minimize external light influence throughout the edge of the specimen. 17 mm aperture was used for color measurements. The spectrophotometer automatically generated three measurements from which it calculated a mean color measurement that was recorded on the computer. Before each measurement, the spectrophotometer was calibrated according to the manufacturer's recommendations by using the supplied white calibration standard. Values of the color change were recorded in the CIELAB color system. The color was measured of the specimens dipped in artificial saliva, which were taken as a standard against which the color change was measured under the different staining solutions at the time interval of 1, 2, and 4 weeks. The color difference was calculated from the means using the following formula:

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

Where ΔL, Δa, and Δb are the differences in L, a, and b values of the specimens in the staining solutions and the specimens in artificial saliva, and ΔE is the color difference between the specimens immersed in staining solutions and specimens in artificial saliva.

Data was analyzed using the Statistical Package for the Social Sciences (SPSS), version 17.0. The p value was taken as significant at 5% level of significance.

The ANOVA test was used to compare the means, and the pair-wise comparison between the materials and staining solutions after different time intervals was assessed by using the *post hoc* (Tukey) test.

RESULTS

The mean color change (ΔE) over a period of 1, 2, and 4 weeks was significantly different relative to the mean color change at baseline (p < 0.05; Tables 2 to 4) for each material as well as each solution. Furthermore, the data shows strong evidence that the pattern of mean color change differed over time (Tables 2 to 4). The analysis also showed that irrespective of the staining solution, the heat-polymerized provisional restorative material (DPI) showed the least color change, while the light-polymerized provisional restorative material (Revotek LC) showed the

Table 2: Analysis of change in color at 1 week: mean color change (ΔE) at 1 week relative to baseline for each material and staining solution

		Mean ΔE				
		Sambhar		Tea		Tobacco
Material	n	Mean* [± SD]	n	Mean* [± SD]	n	Mean* [± SD]
Light cure	10	24.0 [± 0.64]	10	7.3 [± 1.58]	10	2.9 [± 0.67]
Self-cure	10	2.0 [± 0.91]	10	1.4 [± 0.40]	10	1.2 [± 0.43]
Heat cure	10	0.7 [± 0.17]	10	0.8 [± 0.18]	10	0.8 [± 0.49]

*p value < 0.05; SD: Standard deviation

Table 3: Analysis of change in color at 2 weeks: mean color change (ΔE) at 2 weeks relative to baseline for each material and staining solution

		Mean ΔE				
		Sambhar		Tea		Tobacco
Material	n	Mean* [± SD]	n	Mean* [± SD]	n	Mean* [± SD]
Light cure	10	26.8 [± 1.10]	10	8.8 [± 1.08]	10	3.9 [± 0.72]
Self-cure	10	2.9 [± 1.21]	10	2.6 [± 0.73]	10	1.8 [± 0.57]
Heat cure	10	1.1 [± 0.24]	10	1.6 [± 0.47]	10	1.3 [± 0.25]

*p-value < 0.05; SD: Standard deviation

Table 4: Analysis of change in color at 4 weeks: mean color change (ΔE) at 4 weeks relative to baseline for each material and staining solution

		Mean ΔE				
		Sambhar		Tea		Tobacco
Material	n	Mean* [± SD]	n	Mean* [± SD]	n	Mean* [± SD]
Light cure	10	39.8 [± 1.75]	10	11.2 [± 0.67]	10	6.0 [± 0.55]
Self-cure	10	3.8 [± 1.35]	10	4.2 [± 0.95]	10	3.2 [± 0.62]
Heat cure	10	1.8 [± 0.34]	10	2.2 [± 0.88]	10	2.0 [± 0.46]

*p-value < 0.05; SD: Standard deviation
The mean color change (ΔE) for each staining solution under each material from baseline value is significantly different

highest color change after each time interval. Moreover, the mean ΔE values for light-polymerized provisional restorative material in sambhar staining solution were high compared to tea and tobacco staining solutions (Tables 2 to 4). Except for light-polymerized material, no significant difference was observed between each pair among staining solutions (tea, tobacco, and sambhar) after each time interval (Tables 5 to 7; p > 0.05). The pair-wise comparison of different combinations of materials and staining solutions reveals statistically highly significant differences between them after each time interval (p < 0.0001; Tables 5 to 7; Graph 1). These findings indicated the presence of a strong interaction between materials and staining solution regardless of the color considered and further proved the fact that material and staining solutions were not additive in effects, and the difference in color changes between tea, tobacco, and sambhar staining solutions differed with the material in question.

Table 5: Comparison of mean color change at 1 week among the materials and staining solutions and different combinations of material and staining solution

Group – 1		Group – 2			
Material-staining solution	*Mean [± SD]*	*Material-staining solution*	*Mean [± SD]*	*Mean diff. between groups*	*p-value*
LC-Sambhar	24.0 [±0.64]	LC-Tea	7.3 [±1.58]	16.8	<0.001
		LC-Tobacco	2.9 [±0.67]	21.2	<0.001
		SC-Sambhar	2.0 [±0.91]	22.0	<0.001
		SC-Tea	1.4 [±0.40]	22.7	<0.001
		SC-Tobacco	1.2 [±0.43]	22.9	<0.001
		HC-Sambhar	0.7 [±0.17]	23.4	<0.001
		HC-Tea	0.8 [±0.18]	23.2	<0.001
		HC-Tobacco	0.8 [±0.49]	23.3	<0.001
LC-Tea	7.3 [±1.58]	LC-Tobacco	2.9 [±0.67]	4.4	<0.001
		SC-Sambhar	2.0 [±0.91]	5.2	<0.001
		SC-Tea	1.4 [±0.40]	5.9	<0.001
		SC-Tobacco	1.2 [±0.43]	6.1	<0.001
		HC-Sambhar	0.7 [±0.17]	6.6	<0.001
		HC-Tea	0.8 [±0.18]	6.5	<0.001
		HC-Tobacco	0.8 [±0.49]	6.5	<0.001
LC-Tobacco	2.9 [±0.67]	SC-Sambhar	2.0 [±0.91]	0.8	0.23
		SC-Tea	1.4 [±0.40]	1.5	0.001
		SC-Tobacco	1.2 [±0.43]	1.7	<0.001
		HC-Sambhar	0.7 [±0.17]	2.2	<0.001
		HC-Tea	0.8 [±0.18]	2.1	<0.001
		HC-Tobacco	0.8 [±0.49]	2.1	<0.001
SC-Sambhar	2.0 [±0.91]	SC-Tea	1.4 [±0.40]	0.6	0.57
		SC-Tobacco	1.2 [±0.43]	0.9	0.18
		HC-Sambhar	0.7 [±0.17]	1.3	0.003
		HC-Tea	0.8 [±0.18]	1.2	0.009
		HC-Tobacco	0.8 [±0.49]	1.3	0.008
SC-Tea	1.4 [±0.40]	SC-Tobacco	1.2 [±0.43]	0.2	1.00
		HC-Sambhar	0.7 [±0.17]	0.7	0.45
		HC-Tea	0.8 [±0.18]	0.6	0.68
		HC-Tobacco	0.8 [±0.49]	0.6	0.64
SC-Tobacco	1.2 [±0.43]	HC-Sambhar	0.7 [±0.17]	0.5	0.88
		HC-Tea	0.8 [±0.18]	0.4	0.97
		HC-Tobacco	0.8 [±0.49]	0.4	0.96
HC-Sambhar	0.7 [±0.17]	HC-Tea	0.8 [±0.18]	−0.1	1.00
		HC-Tobacco	0.8 [±0.49]	−0.1	1.00
HC-Tea	0.8 [±0.18]	HC-Tobacco	0.8 [±0.49]	0.0	1.00

Table 6: Comparison of mean color change at 2 weeks among the materials and staining solutions and different combinations of material and staining solution

Group – 1		Group – 2			
Material-staining solution	*Mean [± SD]*	*Material-staining solution*	*Mean [± SD]*	*Mean diff. between groups*	*p-value*
LC-Sambhar	26.8 [±1.10]	LC-Tea	8.8 [±1.08]	18.0	<0.001
		LC-Tobacco	3.9 [±0.72]	22.9	<0.001
		SC-Sambhar	2.9 [±1.21]	23.9	<0.001
		SC-Tea	2.6 [±0.73]	24.2	<0.001
		SC-Tobacco	1.8 [±0.57]	25.0	<0.001
		HC-Sambhar	1.1 [±0.24]	25.7	<0.001
		HC-Tea	1.6 [±0.47]	25.2	<0.001
		HC-Tobacco	1.3 [±0.25]	25.5	<0.001
LC-Tea	8.8 [±1.08]	LC-Tobacco	3.9 [±0.72]	4.9	<0.001
		SC-Sambhar	2.9 [±1.21]	5.9	<0.001
		SC-Tea	2.6 [±0.73]	6.2	<0.001
		SC-Tobacco	1.8 [±0.57]	7.0	<0.001
		HC-Sambhar	1.1 [±0.24]	7.7	<0.001
		HC-Tea	1.6 [±0.47]	7.2	<0.001
		HC-Tobacco	1.3 [±0.25]	7.5	<0.001
LC-Tobacco	3.9 [±0.72]	SC-Sambhar	2.9 [±1.21]	1.0	0.08
		SC-Tea	2.6 [±0.73]	1.3	0.009

(Cont…)

(Cont…)

Group – 1		Group – 2			
Material-staining solution	Mean [±SD]	Material-staining solution	Mean [±SD]	Mean diff. between groups	p-value
		SC-Tobacco	1.8 [±0.57]	2.1	<0.001
		HC-Sambhar	1.1 [±0.24]	2.8	<0.001
		HC-Tea	1.6 [±0.47]	2.3	<0.001
		HC-Tobacco	1.3 [±0.25]	2.6	<0.001
SC-Sambhar	2.9 [±1.21]	SC-Tea	2.6 [±0.73]	0.3	1.00
		SC-Tobacco	1.8 [±0.57]	1.1	0.11
		HC-Sambhar	1.1 [±0.24]	1.8	<0.001
		HC-Tea	1.6 [±0.47]	1.3	0.013
		HC-Tobacco	1.3 [±0.25]	1.6	0.001
SC-Tea	2.6 [±0.73]	SC-Tobacco	1.8 [±0.57]	0.8	0.47
		HC-Sambhar	1.1 [±0.24]	1.5	0.00
		HC-Tea	1.6 [±0.47]	1.0	0.11
		HC-Tobacco	1.3 [±0.25]	1.3	0.01
SC-Tobacco	1.8 [±0.57]	HC-Sambhar	1.1 [±0.24]	0.7	0.46
		HC-Tea	1.6 [±0.47]	0.2	1.00
		HC-Tobacco	1.3 [±0.25]	0.5	0.84
HC-Sambhar	1.1 [±0.24]	HC-Tea	1.6 [±0.47]	−0.5	0.91
		HC-Tobacco	1.3 [±0.25]	−0.2	1.00
HC-Tea	1.6 [±0.47]	HC-Tobacco	1.3 [±0.25]	0.3	1.00

Table 7: Comparison of mean color change at 4 weeks among the materials and staining solutions and different combinations of material and staining solution

Group – 1		Group – 2			
Material-staining solution	Mean [±SD]	Material-staining solution	Mean [±SD]	Mean diff. between groups	p-value
LC-Sambhar	39.8 [±1.75]	LC-Tea	11.2 [±0.67]	28.6	<0.001
		LC-Tobacco	6.0 [±0.55]	33.8	<0.001
		SC-Sambhar	3.8 [±1.35]	36.0	<0.001
		SC-Tea	4.2 [±0.95]	35.6	<0.001
		SC-Tobacco	3.2 [±0.62]	36.6	<0.001
		HC-Sambhar	1.8 [±0.34]	38.0	<0.001
		HC-Tea	2.2 [±0.88]	37.6	<0.001
		HC-Tobacco	2.0 [±0.46]	37.8	<0.001
LC-Tea	11.2 [±0.67]	LC-Tobacco	6.0 [±0.55]	5.2	<0.001
		SC-Sambhar	3.8 [±1.35]	7.4	<0.001
		SC-Tea	4.2 [±0.95]	7.0	<0.001
		SC-Tobacco	3.2 [±0.62]	8.0	<0.001
		HC-Sambhar	1.8 [±0.34]	9.4	<0.001
		HC-Tea	2.2 [±0.88]	9.0	<0.001
		HC-Tobacco	2.0 [±0.46]	9.2	<0.001
LC-Tobacco	6.0 [±0.55]	SC-Sambhar	3.8 [±1.35]	2.2	<0.001
		SC-Tea	4.2 [±0.95]	1.8	<0.001
		SC-Tobacco	3.2 [±0.62]	2.8	<0.001
		HC-Sambhar	1.8 [±0.34]	4.2	<0.001
		HC-Tea	2.2 [±0.88]	3.8	<0.001
		HC-Tobacco	2.0 [±0.46]	4.0	<0.001
SC-Sambhar	3.8 [±1.35]	SC-Tea	4.2 [±0.95]	−0.4	1.00
		SC-Tobacco	3.2 [±0.62]	0.6	0.90
		HC-Sambhar	1.8 [±0.34]	2.0	<0.001
		HC-Tea	2.2 [±0.88]	1.6	0.008
		HC-Tobacco	2.0 [±0.46]	1.8	0.002
SC-Tea	4.2 [±0.95]	SC-Tobacco	3.2 [±0.62]	1.0	0.41
		HC-Sambhar	1.8 [±0.34]	2.4	<0.001
		HC-Tea	2.2 [±0.88]	2.0	<0.001
		HC-Tobacco	2.0 [±0.46]	2.2	<0.001
SC-Tobacco	3.2 [±0.62]	HC-Sambhar	1.8 [±0.34]	1.4	0.02
		HC-Tea	2.2 [±0.88]	1.0	0.28
		HC-Tobacco	2.0 [±0.46]	1.2	0.11
HC-Sambhar	1.8 [±0.34]	HC-Tea	2.2 [±0.88]	−0.4	0.98
		HC-Tobacco	2.0 [±0.46]	−0.2	1.00
HC-Tea	2.2 [±0.88]	HC-Tobacco	2.0 [±0.46]	0.2	1.00
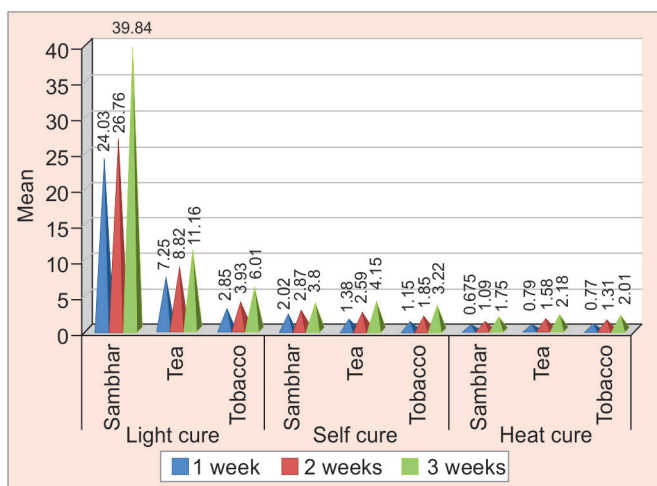
Graph 1: Mean change in color outcome (ΔE) after 1, 2, and 4 weeks for each material and staining solution

The mean ΔE values for heat-polymerized and auto-polymerized provisional restorative materials irrespective of the staining solution were statistically not significant. Figures 1 to 3 show color changes in provisional restorative materials after 1, 2, and 4 weeks respectively.

When color differences were compared in each measurement session, it was observed that the effect of sambhar on heat- and autopolymerized provisional restorative materials was significantly less than on light-polymerized provisional restorative material in terms of color change. The color shift of heat-polymerized provisional restorative material in tea was greater compared to sambhar, but the values were statistically not significant.

DISCUSSION

This investigation evaluated and compared the color changes that occurred when the DPI heat cure, DPI self-cure, and Revotek LC light cure provisional restorative materials were subjected to immersion in tea, tobacco, and sambhar staining solutions after 1, 2, and 4 weeks. These materials chosen were commonly used for fabrication of provisional restorations in routine dental practice.

The color stability of the provisional restorative materials can be affected by various factors,[1-19] but chemical discoloration has been attributed to the oxidation of polymer matrix or oxidation of unreacted double bonds in the residual monomers and the subsequent formation of degradation products from water diffusion.[8] The color changes in the present study showed that the DPI heat cure was most color stable followed by self-cure restorative material, whereas the Revotek LC light cure restorative material was the least color stable. These findings were in agreement with the findings of Crispin and Caputo.[20] The light-polymerized material – Revotek LC – showed significant color change after immersion at all intervals in all the solutions. This finding is similar to the findings by Guler et al.[19] Yannikakis et al[21] found that composite-based resins can absorb water at a higher rate because of high diffusion coefficient in comparison to methyl methacrylate–based resins and thus stain more. According to Haselton et al,[22] bis-acryl polymers are more polar than PMMA polymers and therefore have a greater affinity toward water and other polar liquids and thus are less color stable. It has been proposed that
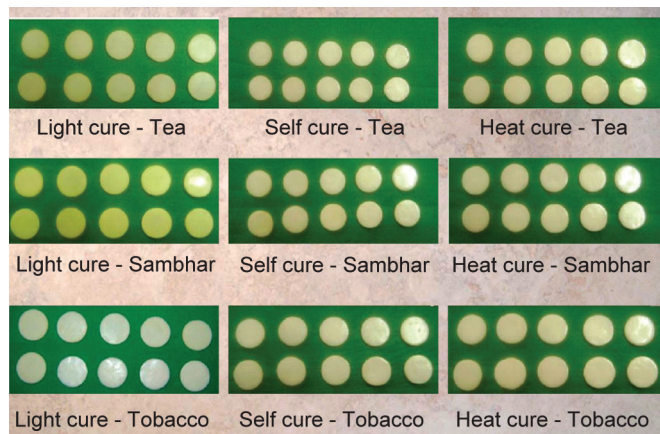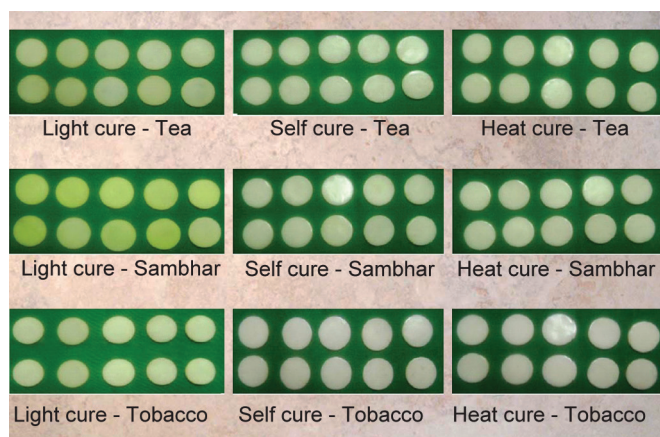

Fig. 1: Color change after 1 week

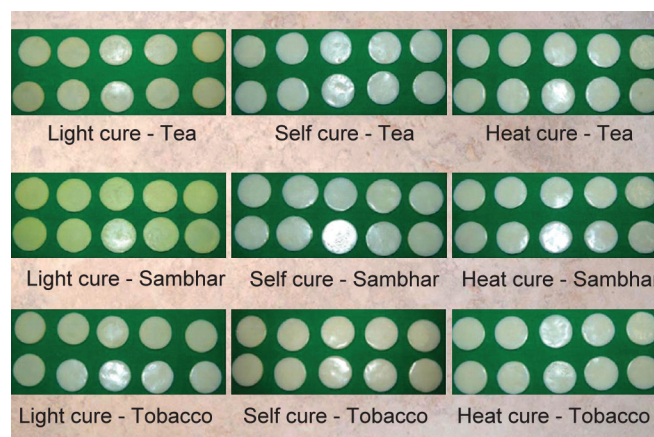

Fig. 2: Color change after 2 weeks

Fig. 3: Color change after 4 weeks

the light-polymerized provisional restorative materials have higher roughness because of larger filler particles and pits resulting in more colorant particle deposition.[19] Heat-cured materials show fewer voids than light-cured materials and have higher polymerization rates and thus are found to be more color stable.[23]

The 20 mm diameter of the specimens used allowed ease in manipulation, handling, as well as positioning of the specimen over the specimen holder as the diameter of the aperture of the spectrophotometer, which was used for color measurements, was 17 mm, while 2 ± 0.5 mm admina corresponds to the thickness that would be achieved after an adequate tooth reduction at the occlusal and incisal surfaces. The specimens were shaped as disks with flat surfaces, as the extraoral spectrophotometer is capable of measuring color only of a flat surface.

In order to standardize the procedures and since pumice polish is routinely used in clinics for finishing of the restoration, the samples were finished using coarse pumice.[24] The specimens were also rinsed with distilled water and gently cleaned with a medium bristle toothbrush to remove any loose sediment resulting from the staining solution and to simulate the oral environment.

Sambhar solution was chosen as it is a curry that contains most of the Indian chromatogenic spices that are added in food routinely, like turmeric powder, red chilly powder, and cooked oil. The tea solution contained sugar and milk powder as this is a routine preparation of this beverage consumed by most of the population. The tobacco solution was prepared by soaking lime-mixed tobacco in distilled water for 30 minutes as on an average each tobacco quid is kept in the oral cavity for a maximum of 30 minutes. The solutions were diluted with artificial saliva in a ratio of 1:2 in order to simulate the oral environment. As the temperature of the solutions can be a factor that could affect the final discoloration, the specimens were immersed in tea and sambhar solution at 50°C, and in tobacco solution at 37°C approximating the temperature of consumption of these beverages. However, they were stored at 37°C in an incubator to simulate the oral environmental conditions. Wozniak et al[25] found that color changes were more in hotter solutions.

Among the solutions tested, sambhar produced a significant difference after 1, 2, and 4 weeks, followed by tea and tobacco solutions. The combination of strong chromatogens and spices being cooked in hot oil could be the reason for the significant discoloration produced by this solution. Hayashi et al[26] and Hachiya et al[12] evaluated the discoloration of composite resins and found that oily foods are a major cause of discoloration. Malhotra et al[27] found that turmeric has the maximum staining capacity, which is attributed to its known high-colorant nature and

natural staining capacity. The yellow color of turmeric is due to curcumin (3%), which is the active substance, also known as Natural Yellow 3. The tea solution showed more discoloration compared to the tobacco solution, but the discoloration caused was clinically acceptable. According to Lai et al,[28] different polar properties of the tested materials affect both the affinity of the material to extrinsic stains and the diffusion of water molecules. Hydrophobic materials are stained by hydrophobic solutions and hydrophilic materials with high water sorption are stained by hydrophilic colorants in aqueous solutions. Yannikakis et al[21] and Gross and Moser[29] found that the staining intensity of coffee was higher than tea and water. Chan et al[30] found that coffee caused more discoloration than tea and cola beverages. In contrast to these findings, Um and Ruyter[8] reported that tea caused more discoloration than coffee after 48 hours of storage of five resin-based materials in coffee and tea solutions. It was also reported that the discoloration by tea was due to adsorption of polar colorants onto the surface of the material, which was removed by tooth brushing, whereas discoloration by coffee was due to both adsorption and absorption of colorants. However, these results cannot be truly compared with that of the present study because of different test materials and different staining solutions used. Tea leaves contain considerable amount of flavonoid, which gives tea its functional properties and flavor; however, teaflavins in tea leaves are reported to be the cause of discoloration, which could be the reason for the stainability of these materials.

The tobacco solution caused changes in color, which were perceivable, but they were within the clinically acceptable range and were most likely due to its tar content.[31]

It was found that the discoloration got accentuated proportional to the time of immersion. This finding is similar to the results obtained by Luce and Campbell.[32] Most of the staining took place within the first 7 days, during which time most of the water sorption takes place.

Khan et al,[33] while studying the physical properties of visible light-cured temporary fixed partial denture material, added an antifungal solution like sodium azide in the solutions tested to prevent fungal growth. However, in the present study the solutions were changed each day, so the antifungal solution was not added.

Spectrophotometer was used to evaluate and compare color change as instrument measurements eliminate subjective interpretation. The color measurements were done in the CIELAB color system, which was developed in 1978 by the Commision Internationale de I'Eclairage for characterizing color for human perception. The CIELAB color system is an approximately uniform color space with coordinates for lightness, namely, white-black (L*),

redness-greenness (a*), and yellowness-blueness (b*). The color difference ΔE is the algebraic distance between two points in the color space. It represents the relative color changes that are observed for the materials after treatment or between time periods. It has been reported by Seghi et al[34] that ΔE value equal to 1 is considered visually detectable 50% of the time, whereas ΔE value greater than 2 is perceptible 100% of the time. Um and Ruyter[8] put forth a threshold that justifies the clinical acceptability of the stained materials and value of $\Delta E = 3.3$ is acceptable, while Guler et al[19] have stated that a value of 3.7 should be considered as visually perceptible. Johnston and Kao[35] assessed appearance matching for composite resin veneer restorations and their comparison teeth using visual criteria established by the United States Public Health Service (USPHS); and extended visual rating scale and clinical colorimetry and found that appearance matched at a value of 3.7. So, in the present investigation, we have considered values $\Delta E > 3.7$ as clinically not acceptable. The color was measured of the specimens dipped in saliva, which were taken as standard, against which the color change was measured after immersion in the different staining solutions. The color measurement was done using a reflectance spectrophotometer that incorporates l0° observer, 45° illumination, with light provided by pulsed xenon arc lamp.

The color stability of any provisional restorative material thus depends on the type of the material, the staining solutions, and the duration of exposure to the staining solutions. This discussion throws some light on the valuable factors that could be responsible for the results obtained in the present investigation.

However, being an *in vitro* study, the oral environment was not simulated completely. In the oral cavity, the flushing effect of saliva as well as the oral hygiene habits may reduce the extrinsic stains on the restorative material. Also, there is limited published knowledge as to how the storage conditions reflect the clinical situation. The solutions employed in this study do not consider all substances to which provisional materials may be exposed and represent media common to the oral environment. In addition to these factors, thermal cycling or abrasion can affect the color stability of the provisional restorative materials, and they require further studies.

CONCLUSION

Within the limitations of this study, following conclusions can be drawn:

- DPI heat cure provisional restorative material is the most color stable.
- Revotek LC light cure provisional restorative material is the least color stable.

- DPI self-cure provisional restorative material has intermediate color stability between heat cure and light cure provisional restorative materials.
- Among the staining solutions, sambhar solution causes maximum discoloration followed by tea solution, while tobacco solution causes minimum discoloration.

Thus, although color stability is only one variable that must be considered when choosing a provisional material, it is of great importance to patients and clinicians when working in the esthetic zone.

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