



Original Research Article

Comparison of color stability of two types of denture base resins in various food colorant solutions: An in vitro study

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ABSTRACT

Background: Heat cured Polymethylmethacrylate (PMMA) and Lucitone are the most commonly used denture base resins but their discoloration results in esthetic problems. There is evidence that these resins get discolored on contact with coloring solutions due to sorption but very few studies report on the effect with food colorants. Hence, this study was conducted to evaluate and measure the effect of these food colorants on the denture base resins.

Purpose: The color stability of two commercially available denture base acrylic resins (Trevalon & Lucitone) was studied in vitro.

Materials and Methods : The specimens were exposed to solution of artificial saliva (control), mixture of artificial saliva and coffee solution and mixture of artificial saliva and turmeric solution. The color measurements were made at baseline (before immersion) and after 30 and 60 days of exposure to staining solutions and color characteristics compared with a white standard using a computer controlled spectrophotometer. Finally, the color stability was quantitatively measured again and color differences (ΔE) were calculated.

Results: The results of discoloration were analyzed with ANOVA, and it indicated that all factors (time, material, and staining solution), and all possible interactions among them, were found to be statistically significant ($p < 0.05$). For the observations made in 30 & 60 days intervals, the specimens that exhibited the least color change were in the artificial saliva (0.92) solution. The greatest color changes observed according to the National Bureau of Standards unit system were Lucitone (8.72) in turmeric solution, Lucitone (7.76) in coffee solution, Lucitone (1.86) in saliva solution. The changes in the other acrylic resin (PMMA) in the 3 solutions were slight and at trace level.

Conclusions: All materials tested were acceptable from the standpoint of color stability for long term exposure to these food colorants. Trevalon[®] (PMMA), demonstrated maximum color stability as compared to Lucitone FRS and discoloration increased proportionally with immersion period.

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1. Introduction

Primary goal of prosthetic dentistry is functional and esthetic rehabilitation of a patient and removable dental prosthesis being simple and non-invasive procedure is a popular treatment option in edentulous patients. The desirable properties of denture base material are ease of

characterization (tinting, pigmented), with no change in color or appearance after fabrication.¹ Denture base resins are susceptible to discoloration in the oral conditions on exposure to various food colorants over a period of time due to absorption & adsorption of fluids rather than color instability of the material itself. Any perceptible color change compromises the esthetics of prostheses.^{2,3} Color stability is an essential quantifiable trait for all dental materials and color change is a sign of aging or

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damage to the materials. Factors like water sorption, stain buildup, ruining of intrinsic pigments, external roughness of the surface and dissolution of the ingredients result in discoloration of dental materials after long-term use. Beverages like coffee, tea, wine and other synthetic food-colorants may escalate the resin discoloration.⁴ Heat cured Polymethylmethacrylate (PMMA) is a universally used denture base resin due to amalgamation of properties such as working characteristics, relative ease of use, low cost, excellent esthetics, accuracy of fit, stability in oral environment and ease of processing.⁵ Recently, nylon based denture materials are gaining popularity in the commercial market because of flexibility and varied dental applications. Routinely used food materials such as tea, coffee, turmeric curries etc tend to have some staining effect on natural dentition and denture base materials. Hence, this in-vitro study was done at Department of Prosthodontics, Delhi Cantt, India, to evaluate and compare the color changes of two types of denture base resins after immersion in a solution of artificial saliva (control), mixture of artificial saliva and coffee solution and mixture of artificial saliva and turmeric solution at intervals of 30 and 60 days with base line color reading of two denture base resins before immersion.

2. Materials and Methods

2.1. Denture base materials

Group 1-Conventional heat cure PMMA denture base resin (Trevalon)

Group 2- Injection molded nylon based denture base resin (Lucitone FRS)

2.2. For preparation of pre-fabricated sheet specimens:

1. Pre-fabricated Bioplast sheet of 2mm thickness (Scheu)
2. Cutter blade.

2.3. For fabrication of heat cure and nylon based injection molded flexible denture base specimens

1. 180 pre-fabricated sheet specimens 50mm×25mm×2mm
2. Injection Molding System & Cartridge Furnace (Success @ Dentsply)
3. Microwave Oven (Bego)
4. Metal flasks and accessories
5. Acrylizing Unit
6. Vacuum Mixing Machine
7. Finishing and Polishing Kit for nylon base materials
8. Digital Vernier Caliper

2.4. For preparation of solutions for storage & evaluation of final specimens:

1. Artificial saliva (Wet mouth, ICPA, New Delhi, India), Coffee Powder (Nescafe, Nestle India, Mysore, India), Turmeric powder (MDH Haldi, New Delhi, India)
2. Digital weighing machine
3. Thermal Incubator (Heraeus Function Line)
4. Gonioreflectometer (Zeiss) (Fig 1.)

Sequence of study:

2.4.1. Preparation of pre-fabricated rectangular specimens

180 rectangular blocks of dimensions 50mm X 25 mm X 2mm were cut from a pre-fabricated acrylic Bioplast (Scheu) sheet of 2mm thickness, invested in Dental stone test specimens were prepared.

2.4.2. Processing & fabrication of denture base material specimens

Specimens in each Group were uniformly processed as per manufacturer's specifications for the respective denture base material. The conventional PMMA specimens were fabricated with compression molding technique and Lucitone FRS specimens with injection molded technique in injection molding system (Success @ Dentsply) (Figure 2). The acrylic resin specimens were finished and polished with standard polishing kits & abraded on both sides with 600-grit silicon-carbide paper to a final thickness of 2.0 + 0.1 mm. Dimensions of 50 mm X 25 mm were verified with Digital Vernier Caliper.

2.4.3. Measuring color readings of resin specimens on a Gonioreflectometer

180 specimens of 12 groups were tested for color readings before immersion and after 30, 60 days of immersion in the solutions. Color characteristics of each specimen were compared with a white standard (Pressed powder tablet of barium-sulfate). The amount of total color change was expressed by a single number

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

where L* stands for lightness, a* for redness-greenness and b* for yellowness-blueness.

Statistical Analysis of color readings - The magnitude of the color changes exhibited by two denture base resins in 3 solutions was compared for equal lengths of time. The results obtained were charted, tabulated (Tables 2 and 3) and statistically analyzed.

3. Results

Within the limitations of the study, the following results were obtained:-

Table 1: Grouping of specimens

	Control- Artificial Saliva (A)			Coffee Solution (B)			Turmeric Solution (C)			Grand Total Of Specimens
	0 Days (I)	30 Days (II)	60 Days (III)	0 Days (I)	30 Days (II)	60 Days (III)	0 Days (I)	30 Days (II)	60 Days (III)	
Gp 1 Trevalon	Gp 1A(I)	Gp 1A(II)	Gp 1A(III)	Gp 1B(I)	Gp 1B(II)	Gp 1B(III)	Gp 1C(I)	Gp 1C(II)	Gp 1C(III)	90
	10	10	10	10	10	10	10	10	10	
Gp 2 Lucitone Frs	Gp 2A(I)	Gp 2A(II)	Gp 2A(III)	Gp 2B(I)	Gp 2B(II)	Gp 2B(III)	Gp 2C(I)	Gp 2C(II)	Gp 2C(III)	90
	10	10	10	10	10	10	10	10	10	
Total	20	20	20	20	20	20	20	20	20	180

1. A “slight” color change of Gp 1 Trevalon (PMMA) in artificial saliva solution and the coffee solution over the duration of 30 days & 60 days whereas “noticeable” change in turmeric solution at 30 & 60 days. (Table 3).
2. A “slight” color change in Gp 2 Lucitone FRs in artificial saliva solution in 30 & 60 days, “noticeable” color change in coffee solution over 30 & 60 days, and “much” change at 30 days and an “appreciable” change in 60 days duration in turmeric solution (Table 3).
3. Analysis of variation of Mean ΔE values of two groups indicated significant differences ($p < 0.05$).
4. Results of repeated measures ANOVA indicated that all factors (time, material and staining solution) and all possible interactions among them were statistically significant ($p < 0.05$) (Table 5).

4. Discussion

Of all the materials available, acrylic resins come closest to the ideal in terms of properties like biocompatibility, superior esthetics and color stability, readily cleansable, acceptable physical and mechanical properties.⁶ Discoloration characteristics of resin-based denture base materials on exposure to food colorant solutions have been reported in studies by Hersek and Zafarullah Khan.^{7,8} Any appreciable color variation in the denture base material results in patient displeasure and additional cost for replacement. Hence, for selection of a denture base material, color stability is one of the essential criteria.^{8–13}

Among drinks, coffee, tea and coke have been identified as the substances which need staining effect evaluation.^{14,15} Coffee and turmeric were used for the study as these are among the most commonly consumed beverages and food component respectively. To simulate the oral conditions, the colorant solutions were based on the readymade artificial saliva and mixed in the ratio of 1:2, the lesser proportion being the actual colorant component. The coffee solution was prepared by mixing 2 gm of coffee powder in 100 ml of distilled water & turmeric solution by mixing 2.9 gm of

turmeric powder in 100 ml of distilled water to simulate the curry solution.¹⁶

Color perception is a psychophysical phenomenon with variations, both among individuals and within an individual at different times. Color changes can be determined by visual assessment and instrument evaluation. Visual color assessment is unreliable as this depends on observer’s psychological response to radiant energy stimulation. Inconsistencies may result due to aging, fatigue, emotional imbalances, illumination, metamerism and object positions etc.^{17–19} Instrumental color measurement obviates the subjective errors of color assessment as it is based on the digital expression of the color perceived from the object. Tristimulus colorimeters provide precise in-vitro measurements and color differences. Therefore, color measurements in the present study were made with help of Gonioreflectometer.

Chromatic differences in dentistry are assessed based on two color systems - Munsell color system and Standard Commission Internationale de L’ Eclairage (CIE Lab). All the colors of nature are obtained through blending of three basic colors (red, blue and green) in varying proportions. The CIE Lab system represents three dimensional color space having components of lightness (L) red-green (a) and yellow-blue (b). CIE Lab color space, used for the color analysis provides information about the location of object color in a uniform 3-dimensional color space.^{2,7,10,15–27}

These tristimulus values were measured three times during the study period; baseline readings, after the immersion in food colorant solutions for a period of 30 days and after immersion for 60 days. Prior to measurements, spectrophotometer was calibrated according to the manufacturer’s instructions by using the supplied white calibration standard. The specimens were placed in the center of the measuring head of a gonioreflectometer.

CIE Lab color difference formula is designed to provide numeric data (ΔE) that represents the magnitude of color difference perceived between two subjects. Apart from color changes with coffee and turmeric, the L^* , a^* , and b^* values

of all the subgroups changed in relation to immersion period. After immersion of test specimens in all the staining solutions, an increase in lightness (increased L^* values) was found for all the sub-groups. The a^* values signified a shift from red towards green while the b^* values signified a shift from blue towards yellow. Color difference (ΔE^*) was calculated by a formula previously mentioned.^{2,7,10,15–27}

4.1. Color changes results

For the observations made in 30 & 60 days intervals, the specimens that exhibited the least color change were in the artificial saliva (0.92) solution. The greatest color changes observed according to the National Bureau of Standards unit system were Lucitone (8.72) in turmeric solution, Lucitone (7.76) in coffee solution, Lucitone (1.86) in saliva solution. The changes in the other acrylic resin (PMMA) in the 3 solutions were slight and at trace level.

The results show that Lucitone FRS produced significant color changes than others in turmeric solution. The least amount of color change was observed in artificial saliva solution (Table 3). The paired t-tests results of the comparison of samples of the two different types of denture base resins – Trevalon & Lucitone FRS in three solutions for the same period, the difference between the initial and 30 days ΔE values in both the solutions of coffee and turmeric solutions was found to be significant ($p < 0.05$). Similarly, the difference in initial and 60 days ΔE values for both Trevalon & Lucitone FRS in solutions of coffee and turmeric was also found to be significant ($p < 0.05$). In the artificial saliva solution, difference was statistically insignificant for pairs at both the durations of 30 & 60 days ($p = 0.195$ & $p = 0.592$, respectively).

The color change results for injection molded flexible denture base resin material, Lucitone FRS, a polyamide type material in the coffee and turmeric solutions (Graph 1) and its comparison with a conventional heat cure resin in this study were consistent with the study conducted by Takabayashi for the same materials in coffee and curry solutions.¹⁶



Fig. 1: Gonioreflectometer (Zeiss) for color assessment on CIELab Scale

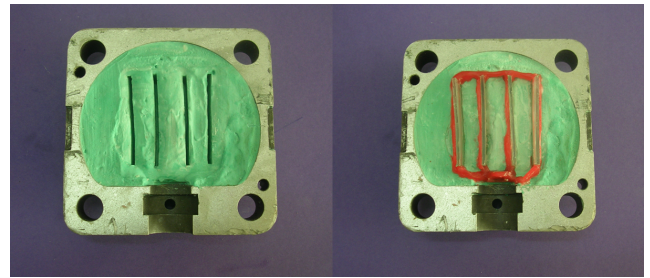


Fig. 2: Flasking of specimens for Injection molded resins

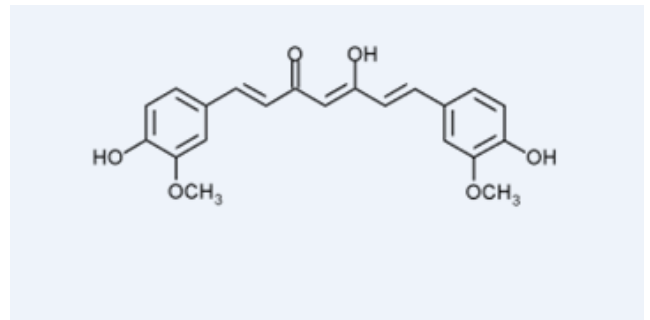


Fig. 3: Chemical formula of curcumin (enol), active ingredient of turmeric

4.2. Reasons / Postulates for Color Changes

Most denture base materials used for prosthesis fabrication are susceptible to absorption and adsorption of fluids based on environmental conditions.²⁸ PMMA absorbs water slowly over time and color change may be due to oxidation of amine accelerator or by presence of traces of different pigments, crosslinking agents and plasticizers, which clarifies the color changing attributes (hydrophilicity) of resins.⁷

The resin samples used in this study were stained with absorption of these colorant solutions, due to polarity of resin molecules following principles of diffusion. The coefficient of diffusion of a heat-cured acrylic resin decreases by fifty percent when there is a drop in temperature from 37°C to 23°C. So, the coefficient of diffusion may be lesser than in-vivo environment.²⁷ Slight discoloration in acrylic resins is result of some interactions with colorant solutions at molecular level. The PMMA denture base resins are hydrophilic, so they have more affinity for water soluble colorants to attach on the surface which is a result of these molecular interactions or electrostatic charges.

Both the materials tested in this study contain chromophores ($>C=O$), which can be easily polarized (Fig.5). The staining in polyamide type nylon based denture base resin materials is possibly a result of interaction between chromophores and free radicals in solution, along with auxochromes ($>N-$) which are also a constituent of the

Table 2: Mean and S.D. of ΔE values of all the various Subgroups at durations of 30 days and 60 days of immersion in the three solutions.

	N	Minimum	Maximum	Mean	Standard Deviation
Group 1A(II)	10	1.01	1.70	1.1700	0.2131
Group 1B(II)	10	0.79	1.54	1.1800	0.2530
Group 1C(II)	10	1.30	3.14	2.2740	0.6546
Group 2A(II)	10	1.00	2.02	1.3400	0.3218
Group 2B(II)	10	1.36	2.18	1.7800	0.2851
Group 2C(II)	10	4.52	8.43	6.3700	1.3127
Group 1A(III)	10	1.15	2.01	1.4600	0.2566
Group 1B(III)	10	0.98	1.85	1.4900	0.2894
Group 1C(III)	10	1.99	3.16	2.4000	0.4155
Group 2A(III)	10	1.13	1.78	1.4000	0.2277
Group 2B(III)	10	1.98	3.54	2.7800	0.4741
Group 2C(III)	10	5.77	9.48	7.7800	1.0539

Table 3: Mean and S.D. of NBS unit values of all the various Subgroups at durations of 30 days and 60 days of immersion in the three solutions.

Samples	N	Minimum	Maximum	Mean	Standard Deviation
Group 1A(II)	10	0.93	1.56	1.0764	0.1961
Group 1B(II)	10	0.73	1.42	1.0856	0.2327
Group 1C(II)	10	1.20	2.89	2.0921	0.6022
Group 2A(II)	10	0.92	1.86	1.2328	0.2961
Group 2B(II)	10	1.25	2.01	1.6376	0.2623
Group 2C(II)	10	4.16	7.76	5.8604	1.2077
Group 1A(III)	10	1.06	1.85	1.3432	0.2361
Group 1B(III)	10	0.90	1.70	1.3708	0.2663
Group 1C(III)	10	1.83	2.91	2.2080	0.3822
Group 2A(III)	10	1.04	1.64	1.2880	0.2095
Group 2B(III)	10	1.82	3.26	2.5576	0.4361
Group 2C(III)	10	5.31	8.72	7.1576	0.9696

Table 4: Critical marks of color difference -National Bureau of Standards

Critical Marks of Difference	Textile Units (NBS Units)
Trace	0.0 - 0.5
Slight	0.5 - 1.5
Noticeable	1.5 - 3.0
Appreciable	3.0 - 6.0
Much	6.0 - 12.0
Very much	>12.0

Table 5: One-Way ANOVA for Mean ΔE values

Source of variation	Sum of Squares	df	Mean Square	F	p-value	Significance
Between Groups	265.742	2	132.871	54.208	.000	Significant
Within Groups	286.785	117	2.451			
Total	552.527	119				

polyamide linkage.¹⁵

The excessive staining observed with Lucitone FRS denture base resins may be related to the rubber phase in its structure. The colorant solutions have electrostatic charges on their structures. Two food colorant solutions selected for this study had charged and ionizable groups in their chemical structure, were water soluble and stable with heat, alkalis, and acids.

The chemical structure of turmeric contains curcumin as an active ingredient which is a polyphenol existing at least in two tautomeric forms - the enol form in solution and the keto form exists in solid phase. (Figure 3) The chemical name is (1E, 6E)-1, 7-bis (4-hydroxy-3-methoxyphenyl)-1, 6-heptadiene-3, 5-dione. Curcumin is a pH indicator. It turns yellow in acidic solutions (pH<7.4) and bright red in basic (pH>8.6) solutions.

Tannic acid, present in tea and coffee caused the staining.^{2,20} In this study, simulation of the oral environment was achieved to some extent using artificial saliva and its incubation at 37°C, but still the effect of the colorant foods was examined in a diet-free medium; however, the actual oral environment is relatively different because of the pellicles formed by the proteins and the glycoproteins in actual saliva that lead to the formation of plaque adhering to the dentures. These soft materials are affected by the food colorant substances more quickly and undergo color changes.⁷

In various dental studies, researchers have used ΔE values to gauge the amount of color changes but criteria of perceptible color changes embraced by each author was different.^{22,29,30} To negate such variations and discrepancies in criteria used, the NBS score system is a gold standard to determine the amount of color change since it proposes exact criteria by which ΔE^* values can be transformed to more meaningful interpretation with remarks with quantifiable clinical significance.

The ΔE^* data obtained from results was converted to National Bureau of Standards units (NBS units) via the formula,

$$\text{NBS units } \Delta E^* \times 0.92$$

Wherein, serious remarks of color change is expressed in NBS units (Table 3), to correlate the magnitude of color change (ΔE^*) documented by the gonioreflectometer to a more clinical environment.

Therefore, in present study, corresponding NBS units were calculated to assess the color differences caused by immersion time and solution type¹⁴. As per National Bureau of Standards (NBS), color change is considered very small if ΔE is less than 1, clinically acceptable if between 1 and 2 and clinically perceptible if ΔE is greater than 3.3 with independent visual assessment made in-vitro under ideal illumination settings²⁷. As per these standards, the grading of nylon based flexible resin material, Lucitone FRS exhibited “much” color change in turmeric solution over a period of 60 days while the traditional heat cure

PMMA resin, Trevalon showed “noticeable” change in both coffee & turmeric solution over both the evaluating periods (Table 4).

5. Conclusions and Recommendations

Within limitations of the study, following conclusions can be drawn and recommendations can be made.

5.1. Conclusions

1. Trevalon (Conventional PMMA) exhibited better color stability as compared to nylon based flexible Lucitone FRS (Injection molded) denture base material after its immersion in different staining solutions for different time periods.
2. Discoloration of denture base materials was directly proportional to immersion period in colorant solution or exposure to food material.
3. Turmeric solution was found to be most chromogenic staining solution

6. Limitations

1. This study has been conducted on only two prototypes of two different types of commonly used denture base resins.
2. Only two chromogenic food substances have been used
3. It has been carried out under simulated oral conditions which is not absolutely same as the actual oral environment.

Hence, It is recommended that further in vivo studies must be conducted on other recently introduced denture base resins using a wider array of food colorants so that a broad based data bank can be generated for choice of ideal denture base material to be used as per the food habits of the patient achieving improved levels of esthetic outcomes and patient satisfaction.

7. Source of Funding

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8. Conflict of Interest

The authors declare they have no conflict of interest.

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