RESEARCH ARTICLE

# Effect of Three Indigenous Food Stains on Resin-Based, Microhybrid-, and Nanocomposites

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## ABSTRACT

***Purpose:*** This study investigated the effects of three indigenous food stains (tea, tobacco, turmeric) on a nanocomposite (Ceram-X-Mono, Dentsply DeTery, Konstanz, Germany), a microhybrid posterior (P60, 3M ESPE, St. Paul, MN, USA), and a universal microhybrid (Z100, 3M ESPE) resin-based composite (RBC).

***Materials and Methods:*** Thirty-six disk-shaped specimens were fabricated (10 × 2 mm) for each type of RBC material, using a polytetraflouroethylene (PTFE) sheet. Specimens from each group were randomly distributed into three subgroups for each of the used stains. The baseline color values were measured using a spectrophotometer. The specimens were immersed in the staining solutions for a period of 3 hours per day for 15 days (3 hours/day × 15 days). Following this, the color change value (ΔE) was calculated.

***Results and Conclusion:*** All the tested groups showed a clinically perceptible color change (ΔE values = 3.3 or >3.3), except for tea-stained P60 (ΔE = 3.15) and Z100 (ΔE = 1.63) groups. Turmeric caused the most significant color change for all the tested RBCs. The least amount of color change was observed with the Z100 (tea, ΔE = 1.63; tobacco, ΔE = 13.59; turmeric, ΔE = 38.77) group that was statistically significant from P60 (tea, ΔE = 3.15; tobacco, ΔE = 18.83; turmeric, ΔE = 57.72), and Ceram-X-Mono (tea, ΔE = 3.32; tobacco, ΔE = 18.83; turmeric, ΔE = 53.95) groups.

## CLINICAL SIGNIFICANCE

The results of this study highlight the variability of interaction between different types of resin-based composites and various stains including turmeric, tobacco, and tea.

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## INTRODUCTION

Beauty is a combination of qualities that delight the sight, other senses, or the mind. Today, because of recent advancement in materials science and the introduction of sophisticated techniques in dentistry, better esthetics along with improved functional durability of a restoration can be achieved. This has enabled dentists to perform smile makeovers for individuals, irrespective of their age, sex, community, or color. Currently, not only for anterior, but adequate color match for posterior restorations is also an important consideration in esthetic dentistry. However, the greatest challenge faced by dentists in clinical practice today is the maintenance of this smile for an acceptable period of time. Unacceptable

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staining/discoloring is commonly encountered in tooth-colored restorations and is a frequent reason for their regular replacement. This discoloration can be attributed to a variety of factors like, the patient's oral hygiene, dietary and smoking habits, and exposure to moisture, food stains, and ultraviolet radiation.[1–5] Staining by colored food agents and various other beverages (tea, coffee, etc.) are among the most common cause for discoloration of resin-based composites' (RBCs) restorations. It is mainly caused by the adsorption of colorant by the resin-based materials.[6] This color mismatch with time is the primary reason for replacement of these restorations (RBCs).[7,8] Discoloration in RBCs can be extrinsic/external discoloration, surface/subsurface discoloration, or internal/intrinsic discoloration.[2,9,10] Extrinsic staining occurs mostly due to either surface roughness of a material (picks up stains) or plaque on the restoration surfaces (absorbs the stain). Intrinsic staining occurs due to diffusion of stain into the RBC and/or materials followed by a chemical reaction with the RBC. The staining ability of a RBC is related to resin matrix,[2,11] content and dimensions of filler particles,[12] degree and depth of polymerization,[4,13,14] curing unit and time,[15,16] polymerization type, adsorption and absorption of stains,[17,18] type of staining agent,[1] and chemical interactions between RBCs and the stains.

The staining of RBCs by coffee/tea (*Coffea arabica*/*Camellia sinensis*) has been widely studied and reported.[18–20] They are important nonalcoholic beverages that act as the main drink in various social gatherings/rituals due to its caffeine content that provides a stimulant effect. Turmeric/Indian Safforn *(Curcuma longa)* has been used as a flavoring and/or coloring agent in a variety of dishes/curries for the past 4,000 years. Apart from this it also possesses anti-bacterial and anti-inflammatory properties that aid in wound healing.[21] India produces almost 80% of the whole world's production of turmeric and is the largest exporter to the Middle East, United Kingdom, United States, and Japan. Introduced by Christopher Columbus, tobacco (*Nicotiana tabacum*) is presently consumed in a variety of chewable and nonchewable forms all over the world. The prevalence of tobacco consumption in chewable form in India is reported to be around 40%.[22] The factors attributed to its consumption can be medicinal factors (relieve toothache), social and cultural factors, media, and personal factors (family practices, influences of friends).[23]

Recently nanohybrid RBCs or nanocomposites have been introduced in the market that are known to possess better handling, strength, and wear properties in addition to excellent polishability without producing light scattering or absorption, leading to better esthetics. A number of studies have shown the discoloring effect of various stains like, coffee, wine, fruit juices/soft drinks, etc. on RBCs,[1,2,8] but the effect of turmeric and tobacco (chewable form) stains on RBCs have not been studied so far. Thus, the aim of this study was to investigate the stainability of a microhybrid posterior RBC (P60), a universal microhybrid RBC (Z100), and a nanohybrid RBC (Ceram-X-Mono, Dentsply DeTery, Konstanz, Germany) on expos e to three indigenous stains, i.e., tea, tobacco, and turmeric after a period of 3 hours per day for 15 days (3 hours/day × 15 days).

## MATERIALS AND METHODS

Specimens of three RBCs were fabricated and then stained with the staining solutions (Figure 1). Using

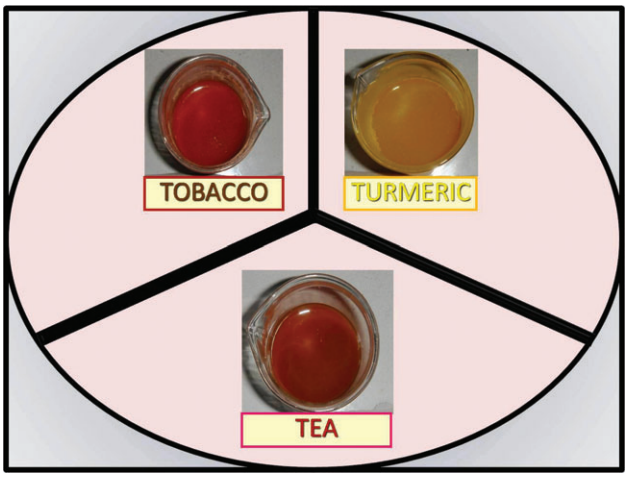


**FIGURE 1.** Prepared staining solutions of tea, tobacco, and turmeric.

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**TABLE 1.** Materials (resin-based composites and staining solutions) tested in the study

| Material | Product | Category | Composition | Manufacturer |
|---|---|---|---|---|
| Resin-based composites | P60 Batch No. 6H29Y | Microhybrid Posterior Composite | BIS-GMA, TEGDMA zirconia/silica fillers (0.01–3.5 μm) 61% by volume | 3M ESPE, St. Paul, MN, USA |
| | Z100 Batch No. 20050412 | Universal Microhybrid Composite | BIS-GMA, UDMA, BIS-EMA zirconia/silica fillers (0.01–3.5 μm) 66% by volume | 3M ESPE, St. Paul, MN, USA |
| | Ceram-X-Mono Batch No. 60701361 | Nanocomposite | Methacrylate modified polysiloxane, dimethacrylate resin, ethyl-4(dimethylamino) benzoate barium-aluminum-borosilicate glass, methacrylate functionalized silicon dioxide nanofiller 62% by volume | Dentsply De Tery, Konstanz, Germany |
| Staining solutions | Taj Mahal | Tea | | Tata Tea Ltd., Kolkata, India |
| | Star Gutkha | Tobacco | | Ghodawat Industries Pvt. Ltd., Karnataka, India |
| | Everest Turmeric | Turmeric | | S. NarendraKumar and Co., Mumbai, India |

spectrophotometry the degree of color change (ΔE*) following staining was measured to compare the stainability of RBCs by different staining solutions.[24,25] RBCs tested were P60 (3M ESPE, St. Paul, MN, USA), Z100 (3M ESPE) and Ceram-X-Mono (Table 1), and staining solutions of tea, tobacco, and turmeric were used (Figure 1). A2 shade of Vitapan® shade guide (Vita Zahnfabrik, Bad Säckingen, Germany) was selected for P60 and Z100 and an equivalent M2 shade was selected for Ceram-X-Mono.

Thirty-six disk specimens were prepared for each RBC tested ($N = 36$), with a total of 108 specimens. The disk specimens for each RBC were further divided into 3 groups ($N = 12$) for each of the three staining solutions prepared. The specimens were fabricated by condensing the composite resin in the polytetraflouroethylene mold having a circular shaped hole (10 × 2 mm) (Figure 2) punched in it. The condensed RBC was then covered with mylar strips (Samit products, New Delhi, India) and sandwiched between the two glass slides on both sides. This was followed by curing on both the sides for 40 seconds using a halogen light curing unit (Elipar™ 2500, 3M ESPE, Seefeld, Germany) at 450 mW/cm$^2$. Each specimen had a diameter of 10 mm and thickness of 2 mm. Following this, all the specimens were placed in a desiccator at 37°C ± 1°C until a constant weight

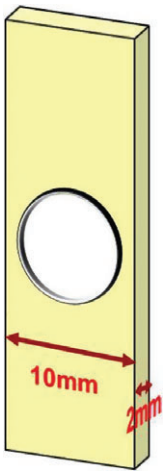


**FIGURE 2.** Dimensions of polytetraflouroethylene mold used for fabrication of resin-based composite disk specimens.

was achieved.[6] Specimens were then stored in distilled water at 37°C for 24 hours to ensure complete polymerization.

Most RBC restorations are polished at the time of insertion. However, based on the composition of the RBC, the polishing of specimens may render different surface characteristics for different RBCs, which can influence the final stain uptake of a material (RBC). Thus, to standardize the procedure and to achieve the smoothest surface possible for all the RBCs, polishing of the specimens was not attempted.


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Twelve randomly selected specimens ($N = 12$) of each RBC were used for the staining process. Taj Mahal Tea, Star Gutkha (tobacco), and Everest Turmeric Powder were used for preparing the staining solutions. Distilled water was used as a control group. Five grams of tea was boiled in 1,000 mL of distilled water for 5 minutes, kept still for 10 minutes, and the supernatant collected was filtered (Whatman no. 1 filter paper, Swastik Scientific Company, Mumbai, Maharashtra, India) and poured into container used for staining the specimens. Similarly, 5 gm of tobacco (three packets) was boiled in 1,000 mL of distilled water for 5 minutes, and 0.15 gm of turmeric powder was boiled in 1,000 mL of distilled water for 5 minutes. Tobacco and turmeric staining solutions were prepared in a similar fashion as the tea solution. Fresh solutions of each stain were prepared and used daily just before the staining procedure. All the specimens were immersed in staining solutions for 3 hours/day in a water bath at 37°C, following which the specimens were stored in a water bath at 37°C until the next day immersion. The specimens were blotted with a blotting paper during transfers to and from the distilled water. All the specimens were immersed in staining solutions for a total period of 3 hours/day × 15 days.

*Commission internationale de l'éclairage* LAB colorimetric system was used for color evaluation. Color evaluation and differences (ΔE*) for each specimen were measured using a spectrophotometer (GretagMacbeth™ SpectroScan, Switzerland) with a standard illuminant D65 and standard observer of 10° under daylight conditions. Color measurements were made just before the immersion ($T_0$-baseline), and after 15 days ($T_{15}$-3 hours/day × 15 days). Before each measurement session, the instrument was calibrated according to the manufacturer's recommendation, by using the supplied white calibration standard. The disks were mounted at 90° relative to the light source. For each specimen, readings were taken three times and mean ΔE* value of three measurements were automatically calculated by the instrument and noted.

The observed color changes (ΔE*) among the three RBCs (Figure 3), following staining with three different stains, were subjected to analysis of variance using

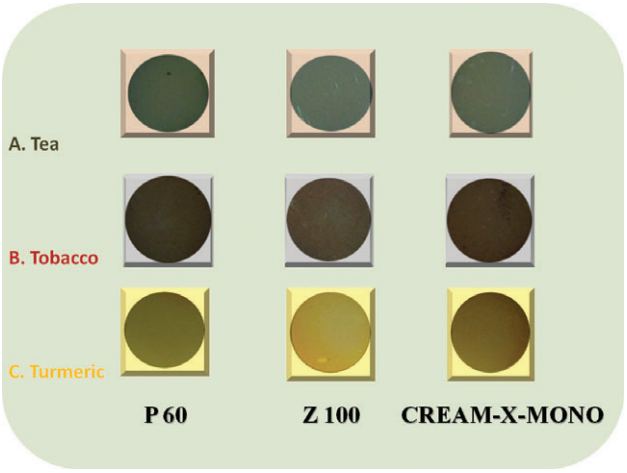


**FIGURE 3.** Stained sample of P60, Z100, and Ceram-X-Mono following exposure to tea (A), tobacco (B), and turmeric (C) stains.

statistical software (SPSS for Windows, Version 11.0.0, SPSS Inc., Chicago, IL, USA). The mean values were compared using Tukey honestly significant difference test ($p < 0.05$).

## RESULTS

The mean values and standard deviations for color change (ΔE*) after a period of 15 days for each combination of staining solutions and tested RBCs are given in Table 2. Except for P60 and Z100 specimens stained with tea solution, all the other specimens showed clinically perceptible color change values (ΔE* ≥ 3.3). The staining capacity of all the used staining solutions were statistically significant for all the tested RBCs ($p = 0.000$). Turmeric showed the maximum staining capacity followed by tobacco, and tea showed the least staining capacity (Figure 4). No statistically significant difference was observed between the P60 and Ceram-X-Mono specimens for all the staining solutions used ($p = 0.234$). Z100 specimens showed the least stainability by all the used staining solutions, which were statistically significant to P60 and Ceram-X-Mono specimens.

## DISCUSSION

In order to replicate the oral conditions following restoration, for this study, the specimens were stored in

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**TABLE 2.** Color changes (ΔE) (mean values and standard deviations) for composites with staining solutions after 3 hours/day × 15 days

| Composite resins | Immersion period | Staining solution | | |
|---|---|---|---|---|
| | | Tea Mean (SD) | Tobacco Mean (SD) | Turmeric Mean (SD) |
| P60 | 15 days | 3.15 (0.99)[a] | 18.83* (2.29)[a] | 57.72* (6.02)[a] |
| Z100 | 15 days | 1.63 (0.35)[a,b] | 13.59* (1.37)[a,b] | 38.77* (9.22)[a,b] |
| Ceram-X-Mono | 15 days | 3.32* (0.99)[b] | 18.83* (3.07)[b] | 53.95* (9.37)[b] |

*Indicates clinically perceptible and unacceptable values (ΔE values = 3.3 or >3.3).

Same superscript letters in the same column indicate statistical significance ($p < 0.05$).

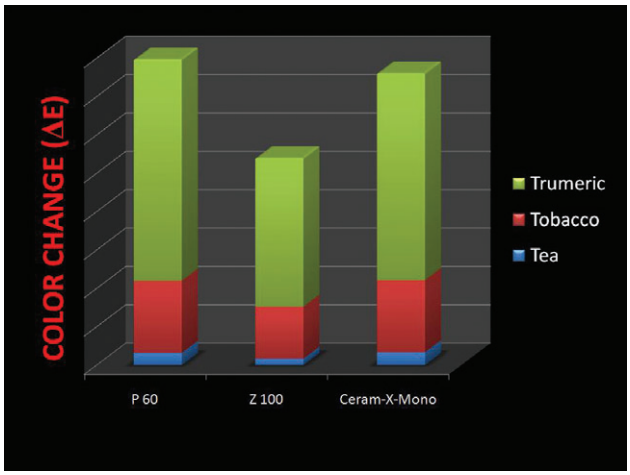


**FIGURE 4.** Graphical representation of observed color changes in tested resin-based composites (RBCs). Staining by turmeric solution was the maximum for the all the three tested RBCs followed by tobacco and tea. P60 and Ceram-X-Mono group showed an equivalent stainability with the three staining solutions. The least stainability was observed in Z100 group.

distilled water for 24 hours following fabrication. The quantity and concentration of staining solutions prepared, immersion time of 3 hours/day (×15 days) in staining solutions, and daily changing of staining solutions were also strictly adhered to closely simulate the in vivo conditions. As the specimens were immersed in concentrated staining solutions daily and continuously for a specified period of time (3 hours/day × 15 days), it could be considered equivalent to a longer duration of exposure to stains in vivo. Tea was preferred over coffee as it is more commonly consumed in this region of the world. Currently, spectrophotometers and colorimeters have been advised and are used to measure discoloration of restorations using the CIE Lab system.[18,24,25] This system inherits the advantage of being repeatable, sensitive, objective, universally accepted, and can measure small color differences.[26] Any color change (ΔE*) in the range of 3.3 to 3.7 and above is considered to be clinically perceptible.[27,28] In the present study, ΔE* ≥ 3.3 was taken as perceptible color change and therefore clinically unacceptable.

Among all the used staining solutions, turmeric showed the maximum staining capacity for all the tested RBCs. This can be attributed to the known high colorant nature and the natural staining capacity of turmeric. The yellow color of turmeric is due to curcumin (3%), which is the active substance, also known as Natural Yellow 3. Difference in particle size and differential solubility of a stain can also be the contributing factors. Other factors involved could be the concentration of the staining solution used, quality of stain (tea, tobacco, and turmeric) used, or difference in interaction of different stains with different RBCs.[19,29,30]

Among the tested RBCs, the least stainability was observed in Z100, whereas P60 and Ceram-X-Mono showed an equivalent amount of stainability by all the used staining solutions. As discussed earlier, the composition of a RBC and the relative amount of resin and filler content present (resin: filler), greatly influence the stainability of a resin material. RBCs having less filler content and more resin content tend to absorb more water at the resin-filler interface,[10] leading to hydrolytic degradation of filler.[31] Thus RBCs with

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relatively lower filler contents have shown to have poor color stability.[32,33] Z100 is a universal RBC containing BIS-GMA, UDMA, BIS-EMA with 66% by volume of zirconia/silica particle fillers having size range of 0.01 to 3.5 μm. P60 is a microhybrid posterior RBC containing BIS-GMA, TEGDMA with zirconia/silica particle as fillers having filler loading of 61% by volume and particle size range of 0.01 to 3.5 μm. Ceram-X-Mono, a nanohybrid RBC has methacrylate modified polysiloxane and ethyl-4(dimethylamino) benzoate in their resin matrix with three different types of fillers, i.e., glass fillers (~1 μm), nanofillers (~10 nm), and organically modified ceramic nanoparticles (2–3 nm), comprising 62% by volume of the total content. Therefore the higher filler content of Z100 could be responsible for its high stain resistant property as compared with P60 and Ceram-X-Mono, which have an approximately equal amount of filler content and thus an equivalent stainability. Also, due to the difference in the resin matrices composition (Table 1) of the different tested RBCs, one particular type of RBC can absorb a particular stain better than the other and influence the degree of staining.[2,34]

Similar results have been reported by Villalta and colleagues[2] and Yazici and colleagues.[10] Villalta and colleagues[2] investigated the effects of coffee or red wine staining solutions on Filtek Supreme (nanohybrid RBC) ($\Delta E^* \cong 12.0$) and Esthet X (microhybrid RBC) ($\Delta E^* \cong 3.9$). Following staining, nanohybrid RBC changed color more than the microhybrid RBC as a result of staining in coffee or red wine solutions. Yazici and colleagues[10] observed the effects of two staining solutions (tea or coffee) on the color stability of a hybrid RBC ($\Delta E^* \cong 4.4$) and a nanohybrid RBC ($\Delta E^* \cong 8.0$) after different immersion periods. Results showed hybrid RBC to be more color stable than the nanohybrid RBC to coffee and tea stains and that stainability is resin-material dependent.

The observed color change ($\Delta E^*$) could be different and to a lesser extent in vivo. A longer staining period may be required in vivo to cause a clinically perceptible color change. This can be attributed to the cleansing action of saliva in the oral activity, and the daily rinsing and brushing action by an individual for oral hygiene maintenance.[19,35] Also, combined treatment of salivary substances (mucin) with stains (chlorhexidine) has not shown to produce any significant (or higher) color changes.[36]

Contemporarily, in esthetic dentistry, it is critical to know the stain-resistant properties of RBCs in order to provide long-term restorations not only functionally but also esthetically. As the three stains used in the study cannot totally characterize the stain resistance of RBCs, the further scope of the study lies in testing the effect of other clinically relevant stains with RBCs of different compositional characteristics (type of resin matrix, filler content, and size).

## CONCLUSION

Within the limits of the current investigation and for the concentrations of the stains tested, the following could be concluded:

1 Turmeric showed the maximum staining capacity for all tested RBCs ($p = 0.000$).
2 Z100 showed better stain resistance than P60 ($p = 0.000$) and Ceram-X-Mono ($p = 0.000$).

## DISCLOSURE AND ACKNOWLEDGEMENTS

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