

ORIGINAL ARTICLE

Influence of staining solutions and whitening procedures on discoloration of hybrid composite resins

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Abstract

Objectives. The aim was to evaluate the color stability and water uptake of two hybrid composite resins polymerized in two different conditions after exposure to commonly consumed beverages. In addition, the effect of repolishing and bleaching on the stained composite was evaluated. **Methods.** Eighty specimens (12 mm × 12 mm × 3 mm) were made from two hybrid composite resins of shade A2. Forty specimens of each composite were divided into two groups ($n = 20$ per each) according to the curing method used (hand light cure HLC or oven light cure OLC). Then each group (HLC or OLC) was subdivided randomly into four sub-groups ($n = 5$), which were immersed for 60 days in different beverages (distal water, coffee, tea and pepsi) and incubated at 37°C. Water uptake was measured during this time and followed by measurement of color difference (ΔE) by using a spectrophotometer. After complete staining, repolishing (grit 4000 FEPA at 300 rpm under water) and bleaching (40% hydrogen peroxide bleaching gel) were conducted. The repolished and bleached specimens were submitted to new color measurements. **Results.** Color value of the specimens immersed in tea displayed the highest statistically significant ($p < 0.05$) mean color difference (ΔE) compared to other beverages, whereas the ΔE value of pepsi was significantly lower than the others. After staining of the composite resins, both the bleaching and repolishing were able to reduce the ΔE value. **Conclusions.** All beverages used affected the color stability of tested composite resins. The effect of beverages on color change of composites depends on type of beverage and water uptake value of resins used. A superior whitening effect was obtained with repolishing technique compared to bleaching.

Key Words: color difference, repolishing, bleaching, composite resins

Introduction

Improvements in adhesive dentistry have resulted in the development of resin-based composite materials which are the most commonly used esthetic restorative materials in dentistry. Color matching of composite resin restorations with the tooth color is good due to an increase in the number of available color shades. In addition, the development of microfilled and nanofilled types of composite resins provide restorations with a good surface finish and smooth texture to give a more natural appearance [1,2]. The success of dental composite resin restorations depends mainly on their surface properties and color stability. However, the discoloration after prolonged

exposure to the oral environment is still a major problem, leading to an unacceptable color match of the restoration, patient dissatisfaction and the additional expense for replacement [3]. Discoloration of restorations can be due to extrinsic or intrinsic causes. Extrinsic causes include accumulation of plaque and surface stains, surface or sub-surface alterations resulting in a superficial degradation or slight penetration and absorption of staining agents to the superficial layer of composite resin [4]. A previous study by Powers et al. [5] showed that the physico-chemical reactions in the deeper portions of the restoration can cause intrinsic stains. The degree of color change can be affected by a number of factors, including the structure of composite resin, the characteristic

of the filler particles, the degree of polymerization and water sorption. Colored food materials and drinks, smoking habits and oral hygiene are also important factors affecting the color of composite resins [6]. Finishing and polishing procedures may also influence composite resin surface quality and can therefore be related to the early discoloration of resins [3]. Even though, the effects of polishing on discoloration are inconsistent among different studies [7,8]. In addition, roughening of the surface cause by wear may affect the gloss and consequently increase extrinsic staining [9].

Dentists are routinely questioned by patients about how long an esthetic restoration should last and if their eating habit may influence the quality and longevity of the restoration. Consumption of certain beverages such as coffee and tea may affect the esthetic and physical properties of composite resins, thereby undermining the quality of the restoration. The consumption of aerated drinks is high in young adults and children. These aerated drinks being acidic may be detrimental to the properties of composite resins. The effect of beverage on the properties of composite resins may also be directly related to the amount and frequency of its intake [10,11].

There are many ways to remove superficial stains from composite resin restorations; for example, tooth brushing, polishing technique or bleaching procedures using either the commercially available bleaching procedure agents or ozone which has been recently used in bleaching because of its strong oxidizing capacity [12]. The removal of stain with tooth brushing is a slower process. Therefore, it is preferred to use more rapid methods, such as polishing or bleaching techniques [13]. An extensive review of the literature showed that there is a contradiction regarding the effect of beverages on composite restorations and effect of repolishing and bleaching on the color change of stained composite resins [6–11]. The present study was undertaken to evaluate the color stability and water uptake of two hybrid composite resins polymerized in two different conditions after exposure to commonly consumed beverages using reflection spectrophotometry, based on the CIE (Commission Internationale de l'Eclairage) L a b color system. Other aims were to clarify the effect of polishing on discoloration resistance and the outcome of repolishing vs bleaching on the color change of stained resin. The tested null hypotheses were that type of beverage and composite resin, curing technique, polishing procedure and water uptake influence the staining of composite resins.

Materials and methods

Eighty specimens (12 mm length × 12 mm width × 3 mm height) were prepared from two brands of hybrid light cured composite resins of

shade A2. Group A ($n = 40$) made from SwissTEC (Coltène/Whaledent, Altstätten, Switzerland) and Group B ($n = 40$) made from Filtek Z250 (3M ESPE, St. Paul, MN) composite resins.

The specimens were fabricated by condensing the material into a silicone mold. Composite resin was pressed by a glass plate and mylar strip to flatten and smooth the surface.

The composite was photo-polymerized for 40 s from both sides using a light source (HLC) with an irradiance of 1200 mW/cm² (Megalux LED, MEGADENTA, Radeberg, Germany). After curing, the mylar strip and glass plate were removed and half of the specimens from each group ($n = 20$) were secondary-cured in an oven curing device (OLC) for 25 min (Megalight ST, MEGADENTA). Specimens were stored dry at room temperature for 24 h before polishing.

Polishing procedure

One side of the specimen surface facing the mold was polished with white stone and diamond polishing cup with low speed hand piece under water cooling and this side was named the polished side. The other side of the specimens facing the glass slide and mylar strip remained unpolished and was named the unpolished side. After polishing, the specimens were rinsed with water and stored dry at room temperature for 24 h before immersion in beverages.

Preparation of beverages

The beverages were prepared in the following concentrations: The tea solution was prepared by immersing three pre-fabricated teabags (Yellow Label Tea, Lipton, Unilever UAE) in 200 ml of boiling water for 5 min. The coffee solution was prepared by adding 2 gm of instant coffee (Nescafe Classic, Nestle, Morocco) to 175 ml of boiling water. The carbonated drink Pepsi (DRC, Dubai, UAE) was used as such. The lids of the containers were tightly closed to prevent escape of carbonic gas. In order to maintain an acceptable level of carbonic gas, a new bottle was used every day and all beverages were changed daily. Distal water was used as a control group (baseline for color change).

Immersion of specimens in beverages

To evaluate the color change in different beverages, 40 specimens of each group were divided into two groups ($n = 20$ per each) according to the curing method used (HLC or OLC). Then each group (HLC or OLC) was sub-divided randomly into four sub-groups ($n = 5$), which were immersed for 60 days in 20 ml of different beverages and incubated at 37°C.

Water uptake

For the purpose of water uptake measurement the specimens were dried and weighted before immersion in beverages and at intervals (1, 2, 3, 5, 7, 14, 21, 30, 40, 50 and 60 days) were removed from beverages, washed with water, dried and weighed then returned to the immersing solutions. The dry weight (m_d) and the weight during immersion (m_w) of the specimens were measured with a balance (Adam Equipment Co., Bond Avenue, UK), with an accuracy of 0.1 mg.

$$\text{Water uptake \%} = (m_{wx} - m_d) / m_d \times 100(\%)$$

where x is days of water immersion.

Color measurements

Color of specimens was measured after 2 months of immersion from both polished and unpolished (glass side) surfaces according to the CIELAB color scale relative to the standard illuminant D_{65} over a white tile (CIE $L^* = 99.25$, $a^* = -0.09$ and $b^* = 0.05$) on a reflection spectrophotometer (CM-700d, Konica-Minolta, Japan). The aperture size was \varnothing 3 mm and the illuminating and viewing configuration was CIE diffuse/8° geometry with the specular component included (SCI) geometry [14]. The color difference ΔE was calculated from the mean ΔL , Δa and Δb values for each specimen using the following formula [15]

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

where ΔL , Δa and Δb are differences in L^* , a^* and b^* values of water stored groups (baseline) and other beverages.

Repolishing procedure

After determination of color variation values, the specimens were repolished (grit 4000 FEPA) at 300 rpm under a water cooler using an automatic grinding machine (Struers Rotopol-11, Copenhagen,

Denmark) with ready-made polishing paste (0.1 μm Alumina paste, Struers Rotopol-11, Copenhagen, Denmark) for 2 min.

Bleaching

Forty per cent hydrogen peroxide bleaching gel (Opalescence Boost 40%, Ultradent, South Jordan, Utah, USA) was painted on the surface of the specimens and left for 40 min at room temperature, then rinsed with water and dried.

The repolished and bleached specimens were submitted to new color measurements, so other values of color variation were obtained.

Statistical analysis

To evaluate the differences in color variation values between the tested specimens in various beverages, data were statistically analyzed with analysis of variance (ANOVA) at the $p < 0.05$ significance level with SPSS (version 13, Statistical Package for Social Science, SPSS Inc, Chicago, IL), followed by Tukey's post-hoc analysis to determine the differences among the groups.

Results

Discoloration of the specimens after 60 days immersion in coffee, tea and peps was easily recognized by the naked eye. Color value of the specimens immersed in tea displayed the highest statistically significant ($p < 0.05$) mean color difference (ΔE) compared to other beverages, whereas the ΔE value of peps was significantly lower than the others.

The mean values of color change of different groups after immersion is summarized in Table I. After 60 days of immersion in tea and coffee, the mean value of color change in Group B composite specimens was significantly ($p < 0.05$) higher than the ΔE value of Group A composite specimens. On the other hand, no statistical difference was found with specimens immersed in peps. As seen in Table I, the smallest ΔE value (0.91) was observed for the polished

Table I. Mean values of color change (ΔE) of different composite resin groups after immersion in beverages for 60 days.

	Group A				Group B			
	Polished		Unpolished		Polished		Unpolished	
	HLC	OLC	HLC	OLC	HLC	OLC	HLC	OLC
Pepsi	2.23	0.91	1.07	1.15	1.87	1.2	1.67	0.84
Coffee	10.66	10.12	11.27	12.47	14.1	10.59	14.02	13.17
Tea	16.1	18.9	16.7	17.75	21.21	19.04	19.05	17.99

Group A, SwissTEC resin; Group B, Filtek Z250 resin; HLC, hand-light cured; OLC, additionally cured in oven light curing device.

oven-light cured (OLC) surface of Group A composite (SwissTEC resin) specimens immersed in pepsi, whereas the greatest ΔE value (21.21) was at the polished hand-light cure (HLC) surface of Group B composite (Filtek Z250 resin) specimens immersed in tea. Additional oven cures had lower ΔE values of all specimens in Group B but not with group A composite specimens. No statistical differences ($p > 0.05$) in ΔE value between polished and unpolished surfaces of composite specimens were found. After staining of the composite resins, both the bleaching and repolishing treatments were able to reduce the ΔE value ($p < 0.05$). As shown in Figures 1 and 2, superior whitening was obtained after repolishing the specimens with a polishing paste over bleaching.

Water uptake (wt%) of Group B composite specimens was higher than Group A composite specimens ($p < 0.05$) (Table II). Oven cured composite specimens in both Groups that were immersed in pepsi had higher water uptake than other composite specimens (Figure 3).

Discussion

Discoloration of composite resin remains a major cause for the esthetic failure of materials and this can be a reason for the replacement of restorations in esthetic areas. This process concerns the patient and dentist and consumes time and money. Staining susceptibility of composite resin might be attributed to the degree of water sorption and hydrophilicity of the resin matrix. If the composite resin can absorb water, then it is also able to absorb other fluids which results in discoloration [6]. It should be noted that in this study a method of measuring water uptake (or weight gain) was used instead of the precisely determined water sorption. Since composite specimens were not dehydrated during measurement of water

sorption at each time point, in composite resins with highly cross-linked matrices, the solubility of the material into water is quite low, so the water sorption and water uptake values can be considered practically equal. The result showed significant water uptake wt% difference between the tested composite resins (Table II). Possibly this is due to differences in the matrix compositions of the materials. Susceptibility of the hybrid composite resins used to staining could be attributed primarily to their water uptake values. Optical properties of composite resin materials are affected with time by degradation due to water uptake and consequent hydrolysis and chemical reactions due to action of tertiary amine and residual camphorquinone [16]. The different susceptibility to hydrolysis of tested composites can be explained by several chemical and physical factors. The hydrophobicity of the matrix and the quality of bonding between silane and fillers can influence water uptake and, consequently, color stability [16]. It is assumed that water acts as a vehicle for stain penetration into the resin matrix [17]. The filler particles do not uptake water into the bulk of the material, but can uptake water onto the surface. Therefore, a greater amount of resin matrix results in greater water uptake and weaker bonding between the resin matrix and filler particles in the composites. Further water uptake may decrease the durability of composite resins by expanding and plasticizing the organic matrix as well as hydrolyzing the silane [18]. The presence of micro-cracks into the resin matrix as a result of swelling and plasticizing effects along with interfacial gaps created between the filler and resin matrix allow stain penetration and discoloration of the restorations [17].

Discoloration can be evaluated by visual and instrumental techniques. Spectrophotometry, used in our investigation, can eliminate the subjective interpretation of visual color comparison and has been reported

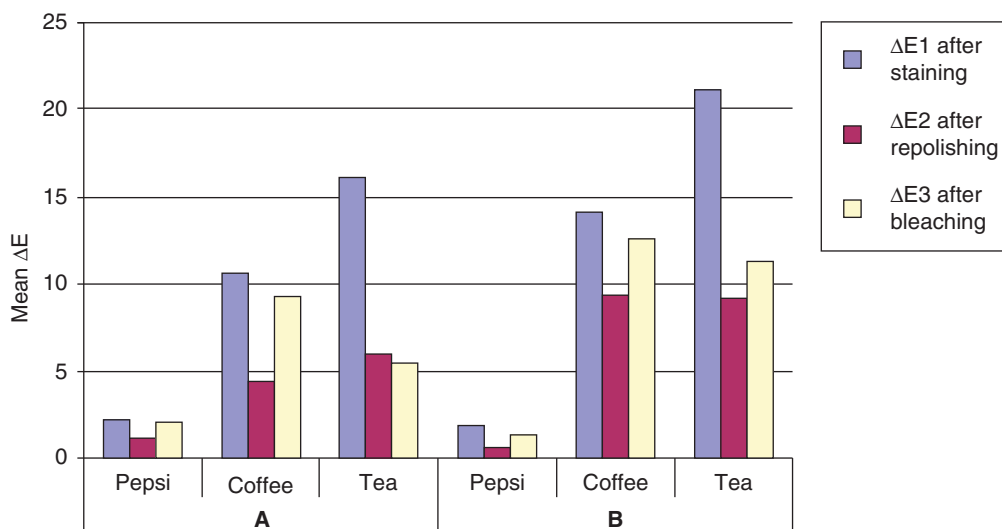


Figure 1. Comparison between the whitening methods used for hand light cured (HLC) specimens after staining for 60 days. Group A: SwissTEC resin; Group B: Filtek Z250 resin.

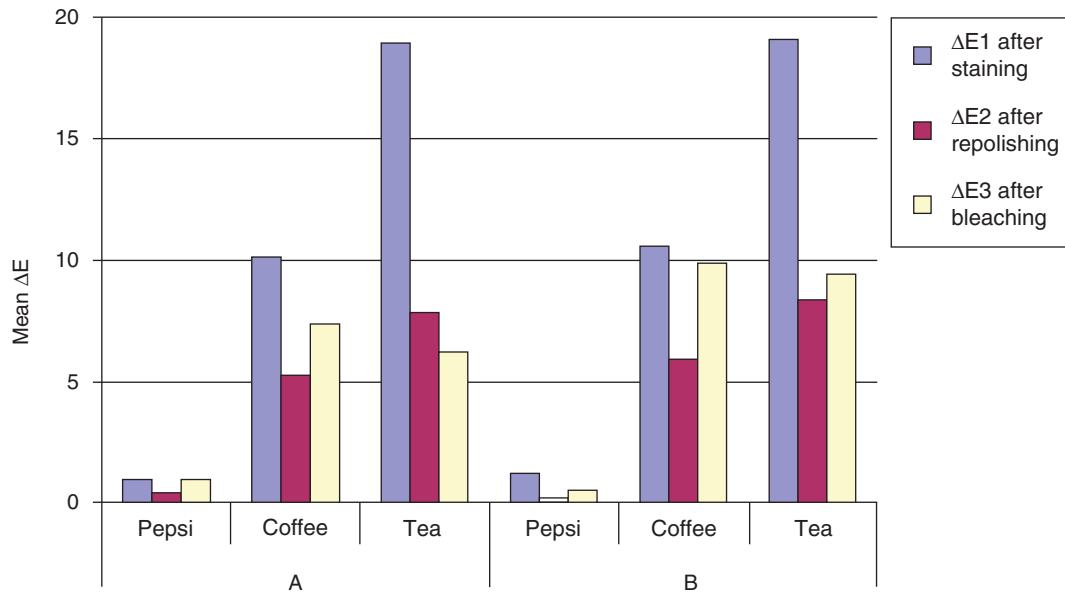


Figure 2. Comparison between the whitening methods used for oven light cured (OLC) specimens after staining for 60 days. Group A: SwissTEC resin; Group B: Filtek Z250 resin.

to be a reliable technique in dental materials studies [19,20]. Color change (ΔE) value represents relative color changes that an observer might report for the materials after immersion or between time periods. Thus, ΔE is more meaningful than the individual L^* , a^* and b^* values [20]. In the present study, the color stability of composite resins was evaluated after immersion in four most commonly used beverages (water, tea, coffee and pepsin). The composite specimens were immersed in beverages for 60 days. A massive review of the literature in the last 10 years showed that maximum immersion time used was 30 days [21,22]. The average time for consumption of one cup of coffee or tea is 15 min and, among coffee or tea drinkers, the average consumption is three cups per day. Therefore, 60 days of storage simulated consumption of the drink over 4 years [9]. Composite resins that can absorb water are also able to absorb other fluids with pigments, which results in discoloration. Color change (ΔE) value in Group B composite specimens was significantly higher than ΔE value of Group A composite specimens after immersion in coffee and tea (Table I). This might be due to the higher water uptake value of Group B composite

specimens (Table II). In accordance with previous investigations, tea and coffee showed the most severe composite discoloration, which was easily recognized by the naked eye [20,21]. Coffee and tea may stain by absorption of their colorants onto/into the organic phase of resin composites [23]. Interestingly, pepsin drink with phosphoric acid does not appear to be strongly implicated in color change of composites compared to coffee and tea, despite the high water uptake value. Acid behaves differently in promoting dissolution and water uptake and hence in eroding the materials. According to Bagheri et al. [17] and Ertas et al. [24], the lack of yellow colorant in pepsin resulted in less discoloration than caused by coffee and tea. Several authors have reported that ΔE values of composite resins ranging from 1–3 are perceptible to the naked eye and ΔE values greater than 3.3 are clinically unacceptable [25,26]. Considering these concepts, the composite resins tested in the present study showed unacceptable color changes when stored in coffee and tea.

The affinity of the resin matrix for stain is also modulated by its degree of conversion (DC%) [27]. The amount of unreacted monomer is directly

Table II. Water uptake (wt%) (SD) of the specimens after 60 days storage at 37°C.

	Group A HLC	Group A OLC	Group B HLC	Group B OLC
D. Water	0.52 (0.08)	0.60 (0.07)	1.03 (0.09)	0.85 (0.07)
Pepsi	0.70 (0.02)	0.91 (0.07)	0.97 (0.08)	1.26 (0.22)
Coffee	0.61 (0.04)	0.67 (0.09)	0.73 (0.07)	1.16 (0.19)
Tea	0.69 (0.09)	0.74 (0.06)	0.90 (0.02)	1.06 (0.12)

Group A, SwissTEC resin; Group B, Filtek Z250 resin; HLC, hand-light cured; OLC, additionally cured in oven light curing device.

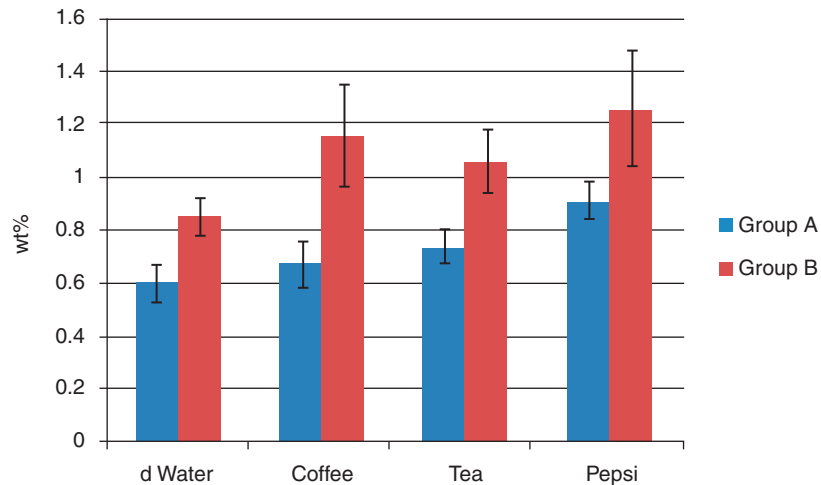


Figure 3. Water uptake (wt%) of oven light cured specimens during 60 days immersion in different beverages. Group A: SwissTEC resin; Group B: Filtek Z250 resin.

dependent on the DC%. Higher monomer conversion indicates a low amount of unreacted monomer, low water uptake and higher color stability. However, in the present study, no significant difference was noted in color change among hand light cured and additionally oven cured composite specimens.

Another aspect reported in the literature that may have an influence on the color stability is polishing techniques [6,28]. Studies have suggested that polished composite resin restorations exhibited better resistance to discoloration [7,8]. In this study, one surface of all composite specimens was polished to closely simulate clinical conditions, i.e. by using diamond-polishing cup. The other surface of composite specimens facing the mylar strip and glass slide was unpolished and considered to be a monomer-rich surface. However, contrary to expectation, the outcome of polishing on color change of composite specimens was not significant (Table I). This is in accordance with Imamura et al. [28], who demonstrated that effect of polishing was not a strong influential factor in composite discoloration.

Once staining occurs, repolishing and bleaching procedures are presumed as whitening procedures can partially and totally remove stains [6]. According to Fontes et al. [29] the pigmented layer of the composite (~ 40 μm) or the absorbed stains could theoretically be removed by polishing [29]. Fay et al. [11] suggested that discoloration of resin composites can be partially removed by in-office bleaching and repolishing procedures.

In this study both repolishing and bleaching were able to reduce the color change value in all composite specimens (Figures 1 and 2). However, ΔE values of coffee and tea specimens were still higher than 3.3, which are not acceptable clinically. The repolishing results of composite specimens immersed in pepsi reversed the color nearly to baseline. Furthermore, the whitening effect of repolishing was superior over

bleaching in most of composite specimens (Figures 1 and 2). This appeared to contradict the result obtained by Türkün and Türkün [13], who reported that polishing was less effective than bleaching because of deeper penetration of staining substance. A study by Elhamid and Mosallam [6] showed no difference between the whitening effect of carbamide peroxide bleaching and repolishing. Such a contradiction may be due to the difference in materials, techniques, beverages and period of immersion. Our results are in agreement with those of Mundim et al. [30], who showed that repolishing after coffee staining reduces the ΔE values of composite resins.

The whitening effect of carbamide peroxide is related to its breakdown into hydrogen peroxide and urea that can be further decomposed to carbon dioxide and ammonia. The high pH of ammonia facilitates bleaching procedures [6]. Hydrogen peroxide breaks down into water and oxygen and in the process generates free radicals, which are very reactive. Such free radicals are responsible for the bleaching process (oxidation). These free radicals oxidize the larger pigmented molecules into small less visible molecules and this might explained the superior effect of bleaching gel on composite specimens immersed in tea [31].

Methodological limitations for *in vitro* studies are inherent in the assessment of color stability. In this study, we tried to simulate the effect of long-term exposure in an oral environment in a short time period (60 days), aiming to predict the clinical performance of the materials. In the oral cavity, the influence of heat caused by hot drinks and hot food, saliva and other fluids may be more significant. In addition, the resin surface roughness was changed by the mastication process and the discoloring factors and deposits can stay longer on rough resin surfaces. Furthermore, the contact of dental structures and restorative materials with staining

agents is intermittent and may be exacerbated by mechanical wear.

Conclusions

Under the conditions of the present *in vitro* study, it can be concluded that all beverages used affected the color stability of tested composite resins. The effect of beverages on color change of composites depends on type of beverage and water uptake value of resin used. Polishing of tested composites before immersion did not influence the discoloration. Superior whitening effect on stained composites was obtained with repolishing technique compared to bleaching.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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