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Discoloration of Resin Composites Induced by Coffee and Tomato Sauce and Subjected to Surface Polishing: An *In Vitro* Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: The purpose of this study is to evaluate and compare color stability of 3 resin based restorative materials when immersed into staining media at 0, 3, 30, 45, 60, and 75 days, and to assess the efficacy of surface polishing in reducing possible discoloration.

Material/Methods: Ninety composite discs were prepared in a custom-made mold (5 mm diameter and 2 mm thick) from 3 different light cured composites (Filtek™ Z250, Harmonize™, and G-aenial). Color differences of all specimens were measured by a spectrophotometer according to the CIE L*a*b* system. After baseline color measurements, 30 discs from each composite group were randomly divided into 3 subgroups of 10 specimens each. Subgroups (n=10) were immersed for 75 days into different staining solutions: coffee, tomato sauce, and distilled water (control). Solutions were changed every week and color measurements were repeated every 15 days. At day 75, color measurements of the specimens were performed before and after surface polishing with aluminum oxide discs. The experimental data were statistically evaluated using repeated measures one-way ANOVA test followed by Tukey's multiple pairwise comparison with a significance level of 5%.

Results: Of the 3 composites, G-aenial reported the highest color change deviation when immersed into coffee (ΔE=8.674), and tomato sauce (ΔE=7.737) at day 75, followed by Harmonize that also exhibited a significant difference for coffee (ΔE=4.7) and tomato sauce (ΔE=3.8) when compared to distilled water. While Filtek™ Z250 did not show any significant difference between the 3 storage solutions (P>0.05).

Only G-aenial had significant color change (P<0.05) after polishing with aluminum oxide discs for all tested samples, whereas Filtek™ Z250 and Harmonize presented no significant difference after surface polishing (P>0.05).

Conclusions: Under the tested experimental conditions, Filtek™ Z250, among the 3 resin-based composites, exhibited the highest color stability when subjected to coffee and tomato sauce as well. Whereas, G-aenial presented the highest color deviation when immersed in both staining media.

Surface polishing effectively reduced coffee and tomato sauce discolorations for G-aenial's specimens and had no significant effect regarding Filtek™ Z250 and Harmonize.

MeSH Keywords: Acrylic Resins • Dental Polishing • Soy Foods

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Background

Dental resin composites have greatly improved in terms of esthetics, durability, and mechanical and physical properties [1,2]. Color modification is a major reason for changing composite restorations, especially in the anterior region. Color stability of composite restorations is necessary to mimic and preserve the appearance of natural teeth and to satisfy patients' demands [3].

Intrinsic and/or extrinsic factors would affect resin composite and modify its color [4,5]. Composition of composites and polymerization conditions such as polymerization depth, filler particles size, photo-initiator, and resin matrix are considered as the main intrinsic factors; [6] whereas water sorption, surface roughness, and patient's dietary habits favor the integration of extrinsic stains into the restoration [6,7].

Resin composites are made of inorganic fillers that bond to organic matrix through a methyl methacrylate-functional silane [8]. A high filler content and consequently a lower monomeric content promoted less water sorption since monomers demonstrate high hydrophilicity [9].

Composite with a high water sorption value is more prone to be affected by staining beverages and food since water acts as a carrier for staining [10]. Also, increased surface roughness induces high biofilm adhesion, and leads consequently to greater material discoloration. Modification of filler concepts and filler particle size affects the resins' surface roughness [11].

An over consumption of staining agents, such as coffee and tea, has been proven to affect the color stability of composite restorations, especially in patients with poor hygiene [12]. Therefore, periodic composite polishing has been proven to be a good solution for extrinsic discoloration [13,14].

Color change can be visually detected, but for accurate assessment, specific instruments are required. Spectrophotometry using the Commission Internationale d'Eclairage (CIE) color model, L*a*b* system was chosen to evaluate color variation ΔE for determining small color variation [15].

People consume coffee and tomato sauce regularly. The first presents high capacity of staining composite resins and natural teeth [16], and the second might affect the color stability of resin composite due to its red color [17]. This present *in vitro* study was conducted to compare color stability of 3 commonly used resin-based restorative materials when exposed to coffee and tomato sauce, and to investigate the efficacy of surface polishing in reducing subsequent stains.

The tested null hypotheses considered that there is no difference in color stability between the 3 groups of composites after exposure to staining media, and that discoloration can be significantly reduced with surface polishing.

Material and Methods

Staining solutions' preparation

Two types of staining solutions were experimentally prepared by diluting the following: 1.5 g of soluble coffee (Nescafé Gold; Nestlé Middle East) in 50 mL of boiling distilled water [18]; tomato paste diluted in water with 1: 1.5 ratio respectively, as used in commonly made recipes; and distilled water was considered as a control solution.

Composite discs' preparation and immersion

Three types of light-cured resin composites were used: Filtek™ Z250, Harmonize, and G-aenial. Information regarding composite type, color of the resin, composition, and manufacturer is given in Table 1.

A total of 90 composite discs from shade A2 with 5 mm of diameter each and of 2 mm of thickness were prepared using the aforementioned 3 selected composite materials. Composite

Table 1. Materials used in the study.

Materials	Initial Shade	Description	Composition	Manufacturer
Filtek™ Z250	A2	Universal microhybrid	Silica, Zirconia, Bis-GMA, UDMA, Bis-EMA	3M ESPE, Dental Products, St. Paul, MN, USA
Harmonize™	A2	nano-filled	Zirconia and silica nanoparticles, Bis-GMA, TEGDMA, Bis-EMA	Kerr Corporation, Orange, CA, USA
G-aenial	A2	microhybrid	Pre-polymerized (Silica, Strontium, Lanthanoid) Silica, Fumed silica, Fluoroaluminosilicate, UDMA, dimethacrylate co-monomers.	GC Dental Products, Tokyo, Japan

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discs were compacted into a custom made perforated silicone mold, pressed between 2 glass plates in order to obtain smooth surfaces, and light-cured from both sides for 40 seconds by means of a LED curing source light of 800 mW/cm^2 (Demi Plus LED Light Curing System, Kerr Corp., USA). Light activation time was performed according to manufacturer's recommendation while output power and performance consistency was periodically controlled with a radiometer (Demetron LED radiometer, Kerr Corp., USA). Discs thickness was controlled using an electronic digital caliper accurate to 0.1 mm (Digimess, São Paulo, SP, Brazil) and standardized for all specimens to ensure complete conversion of light cured composite material [19].

A total of 30 discs from each composite material were randomly divided into 3 subgroups (n=10). Discs from each subgroup were respectively immersed into coffee, tomato sauce, or distilled water for 75 days in 1.5 mL of the respective solutions. During the experiment, solutions were shaken on a daily basis in order to prevent staining particles deposition and were changed every week [6]. At the time of analysis, every disc was handled with tweezers to avoid contamination.

Color measurements

All discs were subject to color measurements repeatedly by the same operator at room temperature, [19] every 15 days [20], under relative humidity between 45% and 55%.

Before each measurement, discs were brushed carefully under running water, dried, and then positioned on a white background to avoid any potential color absorption effect during color assessment [6,19]. All measurements were done using a digital spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany). Experiments were accomplished in the laboratories of the Faculty of Dental Medicine, Lebanese University.

Color measurement after polish

At day 75 and after the last color measurement, specimens were polished under dry condition with aluminum oxide discs (Sof-lex discs, 3M Dental products, St. Paul, MN, USA) from medium to superfine, for 30 seconds per Sof-lex disc at a speed of 10 000 rpm. Specimens were thoroughly rinsed under running water to remove debris [6,19]. The polished specimens had their thickness measured again with the same electronic digital caliper to ensure standardized thickness of 1.7 mm for all discs. A final color measurement was completed after polishing.

Color calculation

Color difference (ΔE) was calculated from the individual values L*, a*, and b* of the CIE system and collected from the spectrophotometer according to the following formula:

$$\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2] \quad [5]$$

ΔE refers the overall color deviation,
ΔL* the deviation of lightness,
Δa* the deviation of chroma,
Δb* the deviation of hue [15].

Statistical analysis

A computer statistical software program (GraphPad Software, Inc., CA, USA) was used to determine the descriptive statistics (mean, standard deviation [SD]) for color measurements. Data are presented graphically as mean±SD of 30 different discs and analyzed, based on Kolmogorov-Smirnov and Shapiro-Wilk normality tests, using repeated measures one-way ANOVA followed by Tukey's multiple pairwise comparison test. *P*-value <0.05 was considered significant.

Results

The means and SDs of color change ΔE are presented in Table 2. Measurements showed high color changes (ΔE) for G-aenial composite. On day 3, ΔE started with 4.383 and increased to 8.674 after 75 days when immersed into coffee. Whereas, values increased from 1.430 to 7.737 when tomato sauce was used. Harmonize ΔE values, after 3 days, recorded a value of 4.845 and remained stable during the 75 days of experiment (4.764) in coffee solution. In tomato sauce, Harmonize exhibited the same stability of ΔE, values began with 3.290 and ended after 75 days with a slight increase (3.801). Regarding Filtek™ Z250, minimal increase was observed in ΔE values. After 3 days of immersion in coffee only 4.275 was registered, and 5.741 at the end of the immersion (day 75). Also, in tomato sauce a minor change was observed from 3.752 at day 3 to 4.197 at day 75.

Figure 1A–1C show the mean and standard deviation of the 3 composites G-aenial, Harmonize, and Z250, respectively, as well as the distribution of the repeated values between the groups. Figure 2A–2C show the mean and standard deviation of the 3 composites separately when they are polished with Sof-lex discs (day 75) and immersed respectively into distilled water, coffee, and tomato sauce. It is clear from Figure 2A that after polishing G-aenial composite kept a higher value of ΔE for both coffee and tomato sauce when compared to distilled water. Whereas, Harmonize and Z250 composite values appeared to be leveled between the 3 solutions.

When comparing coffee solution with distilled water, G-aenial composite showed a significant difference as well as when comparing distilled water with tomato sauce, excluding day 45 and day 60. Also, tomato sauce exhibited a significant difference from coffee starting from day 30 until the end of the experiment.

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Table 2. Mean (standard deviation) of color change value ΔE.

Resin composite	Immersion period	Staining solution			*P*-value
		Distilled water	Coffee	Tomato sauce	
G-aenial	3 Days	1.499 (0.53) ^{A}	4.383 (1.09)* ^{B}	1.430 (0.73) ^{B}	0.00010
	30 Days	2.484 (0.67) ^{A}	7.557 (1.91)* ^{B}	4.000 (1.32)* ^{C}	0.00020
	45 Days	2.431 (1.41) ^{A}	8.103 (3.63)* ^{B}	5.297 (1.27)* ^{A}	0.00020
	60 Days	2.599 (1.94) ^{A}	7.862 (1.03)* ^{B}	5.363 (1.93)* ^{A}	0.00018
	75 Days	2.553 (0.62) ^{A}	8.674 (1.93)* ^{B}	7.737 (1.76)* ^{C}	0.00021
Harmonize	3 Days	2.425 (0.28) ^{A}	4.845 (0.89)* ^{B}	3.290 (0.69) ^{C}	0.00013
	30 Days	3.226 (0.49) ^{A}	5.096 (0.64)* ^{B}	4.459 (1.49)* ^{B}	0.00150
	45 Days	2.190 (0.67) ^{A}	5.286 (1.44)* ^{A}	3.702 (2.23) ^{A}	0.05790
	60 Days	2.964 (0.94) ^{A}	4.874 (1.52)* ^{B}	4.139 (1.85)* ^{B}	0.00520
	75 Days	2.270 (0.87) ^{A}	4.764 (1.28)* ^{B}	3.801 (0.85) ^{B}	0.00030
Filtek™ Z250	3 Days	3.926 (1.31) ^{A}	4.275 (1.34)* ^{A}	3.752 (1.09) ^{A}	0.65540
	30 Days	3.827 (1.18) ^{A}	4.879 (1.30)* ^{A}	4.558 (1.54)* ^{A}	0.25500
	45 Days	3.905 (1.47) ^{A}	5.093 (1.49)* ^{A}	3.558 (1.19) ^{B}	0.04800
	60 Days	3.992 (0.78) ^{A}	5.671 (1.50)* ^{A}	4.706 (1.67)* ^{A}	0.03670
	75 Days	4.290 (2.28)* ^{A}	5.741 (2.25)* ^{A}	4.197 (1.31)* ^{A}	0.76200

* Indicates clinically unacceptable values ($\Delta E \geq 4$). Grouped values with the same superscript are not statistically different ($P<0.05$).

Similarly, Harmonize showed a significant difference between distilled water and coffee as well as between distilled water and tomato sauce during the whole experiment, day 45 can be excluded with an overall *P*-value of 0.05790. Also, between tomato sauce and coffee, only the first measurement (day 3) presented a significant difference. While after the second measurement (day 30) no significant differences were observed.

Filtek™ Z250 results showed no significant difference between all compared groups. Only at day 60 was there a difference between coffee and distilled water, as well as at day 45 when comparing tomato sauce to coffee.

After polishing the samples with Sof-lex discs, no significant difference was observed between all samples regarding both the composites: Harmonize and Filtek™ Z250. While, G-aenial presented a very low overall *P*-value of 0.00015. A significant difference was found between coffee and distilled water, also between tomato sauce and distilled water. The only nonsignificant difference for G-aenial was observed between tomato sauce and coffee (Table 3). In all comparative tests, significant results were paired to high power of the test.

Discussion

Nowadays, esthetic restorative materials are highly requested. Shade match should be achieved initially, and color stability is required subsequently. Therefore, stain ability is as important as other mechanical or physical properties. The present study compared the color stability of 3 different resin composites (Filtek™ Z250, Harmonize, and G-aenial), and assessed the efficacy of surface polishing to reduce staining impact.

Color variation was considered imperceptible for a value less than 1, clinically acceptable between 1 and 4 and unacceptable when values obtained are higher than 4, as many studies also considered Δ values ranging between 1 and 3 as perceptible to the naked eye, and those greater than 3.3 as unacceptable [21].

The 3 types of composites in this study did not present similar color stability. This might be attributed to their degree of water sorption [22], and the hydrophilicity of the organic matrix [23]. Water sorption is the ability to absorb not only water but also fluids with pigments in the composite's resin matrix. Therefore, increased resin matrix volume induces higher water sorption [23]. Furthermore, the high number of unreacted monomers indicates low degree of conversion, and promotes higher solubility [24], and decreased color stability. Under identical conditions, some monomers present lower degree of conversion than others in the following order: Bis-GMA< Bis-EMA<

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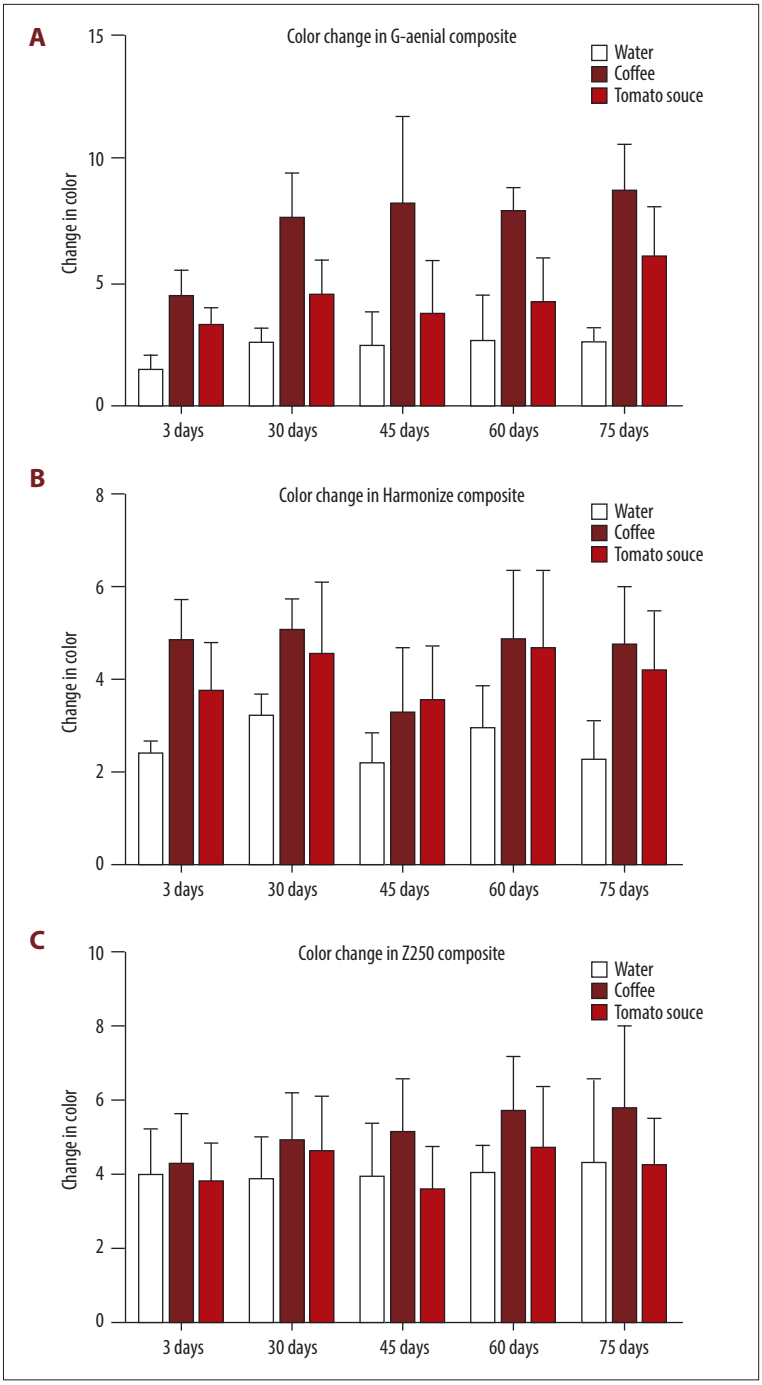

Figure 1. (**A**) Graphical representation of G-aenial analytical study of the repeated measurements. (**B**) Graphical representation of Harmonize analytical study of the repeated measurements. (**C**) Graphical representation of Z250 analytical study of the repeated measurements.

UDMA< TEGDMA [25]. Accordingly, G-aenial's high ΔE deviation might be due to dimethacrylate co-monomers than to UDMA. In this present study, the combination of (UDMA-Bis-GMA-Bis-EMA) in Filtek Z250 presented a higher color stability than the combination of (TEGDMA-Bis-GMA-Bis-EMA) in Harmonize.

Fillers size may influence composite's color stability as well by affecting its surface roughness and polish ability. Lower particle size promotes smoother surfaces; Thus, hybrid composites present higher Δ values compared to other types of composites [26]. Regardless the filler particle size, higher amount of inorganic fillers indicates a smaller resin matrix volume that induces reduced water sorption and increased color stability. In this study, Filtek™ Z250 and G-aenial are both micro-hybrid but the first has higher filler percentage (82%) compared to the second (63%) [27]. Consequently, Filtek™ Z250 presented the lowest ΔE mean values for its reduced resin matrix volume, followed by Nanofilled Harmonize for its smooth surface.

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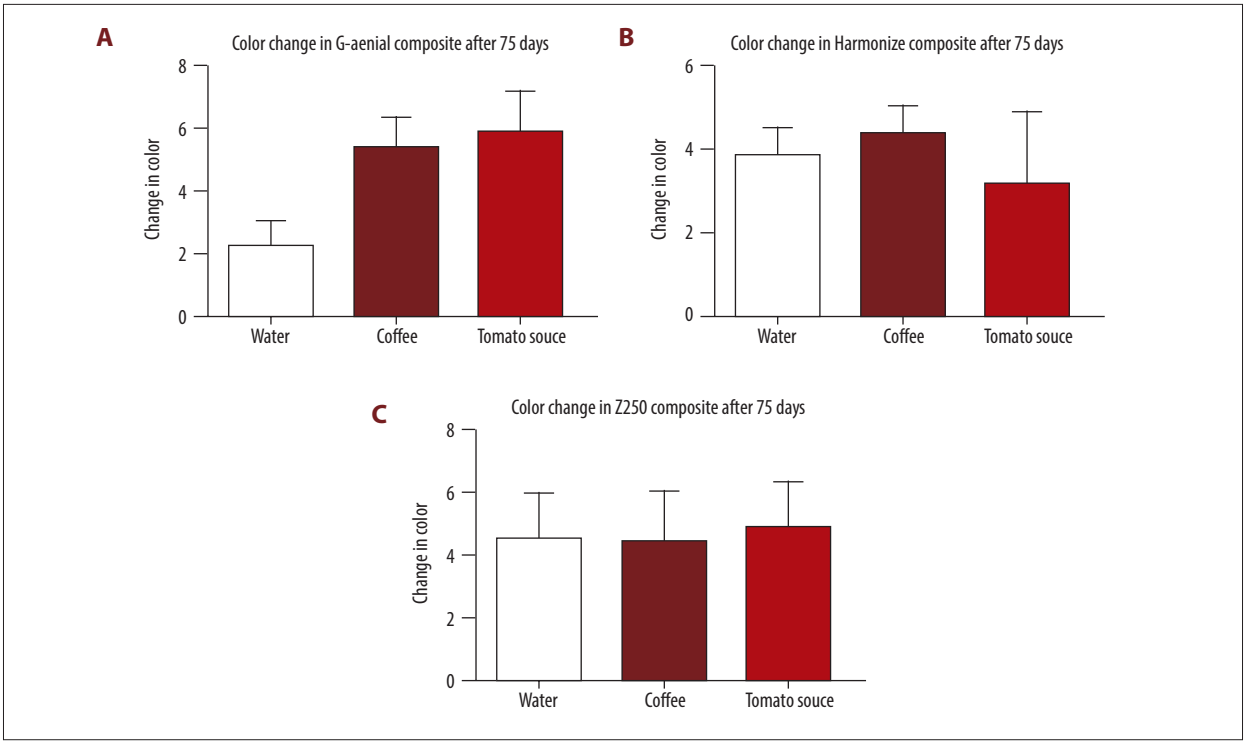

Figure 2. (**A**) Color difference after polishing G-aenial composite. (**B**) Color difference after polishing Harmonize composite. (**C**) Color difference after polishing Z250 composite.

Table 3. Statistical analysis at day 75 post-polishing.

Resin composite	Immersion period	Staining solution			*P*-value
		Distilled water	Coffee	Tomato sauce	
G-aenial	75 days with polish	2.226 (0.84) ^{A}	5.416 (0.92)* ^{B}	5.948 (1.25)* ^{B}	0.00015
Harmonize	75 days with polish	3.871 (0.70) ^{A}	4.423 (0.69)* ^{A}	3.217 (1.72) ^{A}	0.131
Filtek™ Z250	75 days with polish	4.543 (1.49)* ^{A}	4.446 (1.64)* ^{A}	4.863 (1.51)* ^{A}	0.82

* Indicates clinically unacceptable values ($\Delta E \geq 4$). Grouped values with the same superscript are not statistically different ($P<0.05$).

Besides composite's type and composition, storage time greatly influenced composite's water sorption [28]. According to Guler et al., the average consumption of 1 cup of coffee is 15 to 20 minutes and among coffee drinker, the average consumption is 3.2 cups per day; therefor, 15 days of storage simulated consumption of the drink over 1 year [20], and the 75 days simulated 5 years of consumption. *In vitro* results were 24 times more intense than regular daily coffee consumption; Therefore, to simulate *in vitro* number of days to *in vivo* results, the following formula could be useful:

(Σ experimental days×24)/Number of days per year).

G-aenial presented the highest ΔE deviation at day 75 for both coffee and tomato sauce equivalent to 5 years of regular consumption. Harmonize achieved its highest color change in coffee at day 45 (3 years), and in tomato sauce at day 30 (2 years). Filtek™ Z250 had his highest discoloration mean value in coffee at day 75 (5 years) and in tomato sauce at day 60 (4 years). Consequently, discoloration may occur at different storage time regarding resin composites and immersing media types.

Acid food and beverages may induce discoloration by affecting surface integrity [29] and promoting dissolution [30]. In this study, black coffee (pH ranges around 5) had higher staining capacity than tomato sauce (pH ranges around 4.5) [31] as presented in Table 2. It could be concluded that food chromogens are more implicated in color change than the presence of acids.

Although other accomplished studies have suggested that pigments could be removed by surface polishing [32,33], this

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present study reported that no significant change ΔE is noted after surface polishing with aluminum oxide discs except for G-aenial ($P<0.05$). It could be due to the large amount of fillers present on the surface of G-aenial, thus allowing a bigger contact with polishing discs and improving staining removal, or even pigments could be distributed between the surface and underlying layers.

Conclusions

In conclusion, the 3 groups of composites did not present the same color stability upon exposure to staining solutions; G-aenial delivered the highest color change, followed by Harmonize, whereas Filtek™ Z250 was associated with high color stability. Harmonize and Filtek™ Z250, in opposite to G-aenial, did not have significant differences regarding color shift after polishing with aluminum oxide discs.

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Conflict of interest

None.

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