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ORIGINAL RESEARCH ARTICLE

The Effect of Various Beverages, Acidulated Phosphate Fluoride and Home Bleaching on the Color of Restorative Materials

Kerem Yılmaz [1,2], * and Fehmi Gönüldaş [3]

[1]Department of Prosthodontics, Faculty of Dentistry, Antalya Bilim University, Antalya, Türkiye and [2]Bilimdent Oral and Dental Health Center (ADSUAM), Antalya Bilim University, Antalya, Türkiye and [3]Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Türkiye

*Corresponding Author; drkeremy@hotmail.com

Abstract

Purpose: To investigate the effect of acidic beverage, home bleaching agent, immune-boosting beverage with Sambucus nigra (black elderberry) and acidulated phosphate fluoride (APF) on color.
Materials and Methods: Nanohybrid resin composite (NRC) (n=42) and CAD/CAM feldspathic ceramic (FC) (n=42) specimens were prepared. After baseline color change measurements, immersion in distilled water, immersion in lemon juice and bleaching groups were formed. After the first application, immersion in beverage with black elderberry with or without APF application was performed. Measurements were repeated at the end of the first application and on the 12th and 24th day of the second application. Statistical analysis was performed by 2-way ANOVA and Bonferroni tests. The significance level was set as $p<0.05$.
Results: The results obtained for the first application were statistically significant ($p<0.05$). The results obtained for the entire first and second applications were significant only in terms of material ($p<0.05$). In the first application, the highest color change was in bleached NRC ($\Delta E=2.9$, $p=0.0112$) and the lowest in FC immersed in distilled water ($\Delta E=0.4$, $p=0.0084$). At the end of the second application, NRC tended to color change more than FC, regardless of whether APF was performed before immersion in beverage with black elderberry ($p>0.05$).
Conclusions: For FC and NRC specimens, it could be reported that bleaching, lemon juice or immune-boosting beverage with black elderberry caused clinically perceptible color change, but the application of APF prior to immersion in beverage with black elderberry did not cause significant color change.

Keywords: Acidulated phosphate fluoride; Beverage; Bleaching; Color

Introduction

Resin composites (RC) and ceramics have been used for many years to improve the appearance of teeth. Computer-aided design and computer-aided manufacturing (CAD/CAM) restorations have become more popular than conventional restorations because they are more homogeneous and have minimal errors. A restoration must resist color change for a long time, whatever the production method. The main factors affecting color stability are internal factors such as aging and material composition, and external factors such as plaque accumulation and adhesion of colorants to the surface. [1,2]

Low pH can lead to surface degradation of restorative materials. The greater the roughness, the greater the retention of coloring pigments in foods and beverages on the surface, resulting in more extensive color change of restorations over time. [3] In resin-containing materials, the acidic environment leads to weakening of the resin bonds, erosion of the filler particles and breaking of the resin-matrix bond. [4] In ceramics, selective leaching of alkali ions leads to aqueous corrosion of glass. [5]

Bleaching is one of the most commonly used applications to improve the color of teeth discolored by beverages and is performed by the dentist using high concentrations of hydrogen peroxide (HP) in the office or by the patient using low concentrations of carbamide peroxide (CP) at home. It has been reported that when the bleaching agent comes into contact with the restorative material, it will dissolve into the material, disrupting the surface integrity of the material and consequently increasing the likelihood of discoloration over time. [6,7]

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Table 1. Materials used in the study

	Name	Code	Type	Composition	Manufacturer
Restorative Material	RubyComp Nano	NRC	Nanohybrid resin composite	80% barium glass and nanosilica, 20% resin (UDMA, BisGMA, TEGDMA)	İncidental, İstanbul, Turkey
	Cerec C CAD/CAM blocks	FC	CAD-CAM Feldspathic glass ceramic	56–64% SiO_2, 20–23% Al_2O_3, 6–9% Na_2O, 6–8% K_2O	Sirona Dental, Beinsheim, Germany
First application	Whiteness Perfect %16 Home Bleaching Agent		At-home bleaching gel	16% carbamide peroxide, neutralized carbopol, glycerin, distilled water	FGM Dental, Joinville, Brazil
	Freshly squeezed lemon juice				
	Galenik Distilled Water	DW		Distilled water	Galenik Ecza, İzmir, Turkey
Second application	Sambucol Blackberry Plus		Immune-boosting food supplement with black elderberry	Sambucus Nigra fruit extract, 60 mg vitamin C, 7.5 mg zinc, beetroot red (coloring), citric acid, and other ingredients	Pharmacare Europe, West Sussex, UK
	Polimo APF	APF	APF anti-caries gel	1.23% topical ions of acidulated phosphate fluoride	Imicryl Dental, Konya, Turkey

Another application that has the potential to degrade the surface of restorative materials is the application of acidulated phosphate fluoride (APF).[8,9] It has been reported that APF, which has a caries preventive property thanks to its fluoride content,[10] has the potential to degrade the surface of the dental material and subsequently cause color change and this is caused by the hydrogen and fluoride ions that form hydrofluoric acid.[11]

The color of the teeth can be impaired by the adhesion of coloring pigments in consumed beverages to the teeth. Studies investigating beverage-induced color change on the surface of restorative materials are mostly on tea, coffee, cola and wine.[12] Immune-boosting beverages with Sambucus nigra (black elderberry) used to support treatment during the COVID-19 pandemic are likely to disrupt the surface of dental materials due to their acidic character, however, the number of studies examining the effect of such beverages on color of CAD/CAM restorative materials is insufficient.[13]

For the aforementioned reasons, the aim of this study was to investigate the effect of acidic beverage, bleaching, APF and immune-boosting beverage with black elderberry on the color of dental restorative materials. The null hypothesis was that there would be no color change in specimens immersed in lemon juice, applied bleaching, immersed in black elderberry beverage or immersed in black elderberry beverage after APF application.

Material and Methods

In this study, a total of 84 specimens were prepared in accordance with previous studies.[14,15]

The specimens were randomly divided into two equal groups. Half of these specimens were a nanohybrid resin composite (Ruby; Incidental, Turkey) (NRC) and the other half were a CAD/CAM feldspathic ceramic (Cerec C blocks; Sirona Dental, Germany) (FC). The materials used in the study are listed in Table 1.

NRC specimens were prepared by pressing the material between two glass slides. The internal dimensions of the metal mould were adjusted to produce 10 x 12 x 1.5 mm specimens. Each specimen was polymerized with a halogen light source (Ellipar DeepCure-S; 3M ESPE, Germany) for 40 s. Polishing was performed using a composite polishing kit (Clearfil Twist DIA; Kuraray Noritake, Germany). FC blocks were cut to a thickness of 1.5 mm using a specimen cutter (Micracut 201; Metkon, Turkey). Polishing was performed using a ceramic polishing kit (Eve Dianyst Plus; Ernst Vetter, Germany). The thickness of all prepared specimens was measured with a micrometer (Absolute, Mitutoyo, Kawasaki, Japan) and stored in distilled water at 37°C in an incubator (INP-500; Memmert, Germany) for 24 hours to ensure standardization.

The study design is shown in Figure 1. FC specimens (n=42) were divided into FC1 group (n=21) and FC2 group (n=21) and likewise, NRC specimens (n=42) into NRC1 group (n=21) and NRC2 group (n=21). The specimens were randomly selected at the time of grouping.

There were two consecutive applications in this study. In the first application stage, three different applications were performed: home bleaching (n=7), immersion in lemon juice (n=7) and immersion in distilled water (n=7) (DW). The specimens were randomly selected at the time of grouping. In the second application stage, FC1 and NRC1 groups were immersed in beverages with black elderberry (n=42) (SAM group). FC2 and NRC2 groups were first subjected to APF application, followed by immersion in SAM (n=42) (APFSAM group).

Procedures such as preparation of the specimens and taking surface measurements were carried out by the researchers involved in the study. As far as possible, the researchers carried out the work in parts. The allocation of tasks and the sequence of workers in successive sessions were planned randomly.

In the bleaching groups, 16% CP gel was applied to the specimen surfaces at room temperature. After 4 hours of application, the specimens were washed in distilled water, rinsed and dried with tissue paper (Selpak; Eczacıbaşı, Turkey). To simulate the clinical situation, the specimens were immersed in DW at 37 °C between bleaching sessions. Bleaching was performed once a day for 14 days.

According to the manufacturer, the average consumption time for 3.2 grams of tea is 15 minutes. In this case, 24 hours of storage is equivalent to approximately 1 month of consumption. Therefore, in this study, a 14-day immersion period was used to simulate a 1-year period, and color was measured after 2 weeks.[16] Lemon juice and DW were replenished daily throughout the immersion period. Fresh lemons were used for lemon juice. Fresh lemons, squeezed into a container, were syringe-filled into 10 ml opaque specimen storage containers, each containing a single specimen. The specimens were stored in their own plastic containers and the containers were coded to avoid confusion. The DW was placed in a 10 ml container in the same way.

After the first application, the second application was started and this application continued for 24 days. The beverage with black elderberry was prepared by dissolving one effervescent tablet in 150 ml of water at room temperature according to the manufacturer's instructions. In the SAM group, the beverage was injected with a syringe into 10 ml opaque specimen storage containers. In the APFSAM group, APF gel was applied to the surfaces before immersion in the beverage. The American Dental Association recommends APF application 4 times per year for 4 minutes each in high-risk individuals.[9] To simulate 2 years of APF application, the APF application time was set to 32 minutes. APF applied specimens were immersed in the beverage after the surfaces were rinsed under

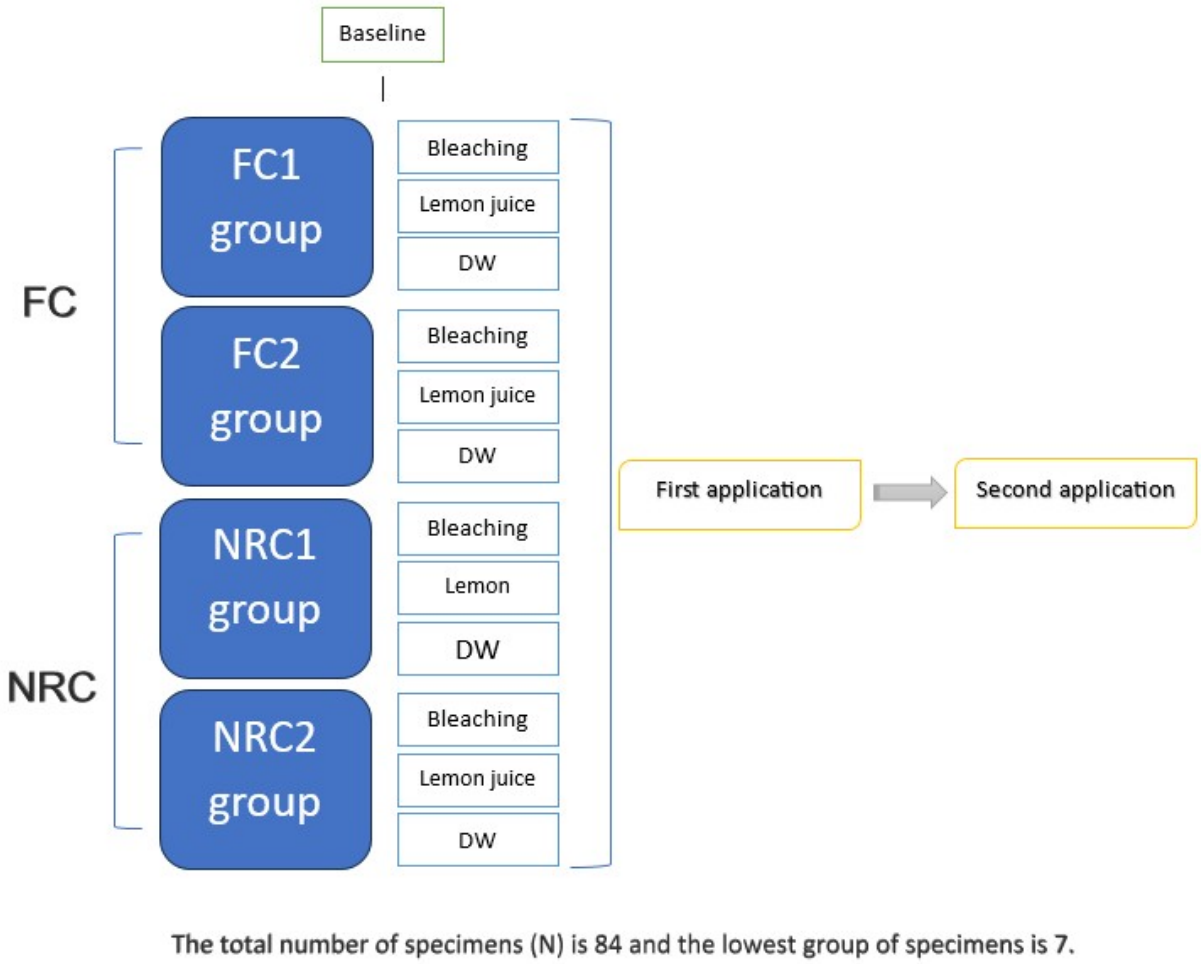

Figure 1. Design of the study

FC: Feldspathic ceramic; NRC: Nanohybrid resin composite; DW: Distilled water. Baseline measurements were taken from the specimens before the first application. The first application consisted of bleaching, immersion in lemon juice and DW. The second application consisted of immersion in a beverage with black elderberry for the FC1 and NRC1 groups and immersion in a beverage with black elderberry after application of acidulated phosphate fluoride for the FC2 and NRC2 groups.

water and dried.

Throughout the process, color measurements were taken at certain stages.These stages were as follows: For the first application, before the start of the application on prepared specimens (baseline measurements) and 2 weeks after baseline; for the second application, 12 and 24 days after the start of the second application.

Color measurements were performed using a spectrophotometer (Vita Easyshade V; VITA Zahnfabrik, Germany). Three measurements were taken from the buccal surface of each specimen. The color change was calculated using the following formula including the parameters L*, a*, b*[17]:

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

In order to standardize the environmental conditions during the measurements and to prevent ambient light from causing errors in the color measurements, all color measurements were performed in a custom-made color measurement booth. The booth was covered with neutral grey cardboard. A lamp (TL-D 90 De Luxe 65000K; Philips, Netherlands) was placed in the booth to simulate daylight, and measurements were performed in a dark room.[18]

Statistical analysis was performed using the SAS software package (SAS 9.4; SAS Institute, USA). 2-way ANOVA followed by Bonferroni analyses was used to evaluate the interaction between material and first application and the main effects of each variable on the color change during the first application. A second analysis was performed using 2-way ANOVA followed by Bonferroni tests to evaluate the interaction between material and the entire first and second applications and the main effects of each variable on the color change over the entire application period (α=0.05).

Results

The results of the 2-way ANOVA test of the first application are shown in Table 2. According to the results, the effect of material, first application and material-first application on color change was statistically significant ($p<0.05$).

The results of the Bonferroni test for the first application are shown in Table 3 and Table 4. When the color change between baseline and week 2 was examined by material, statistically different results were found between FC and NRC ($p=0.0083$). The color change of the NRC ($\Delta E=2.2$) was higher than that of the FC ($\Delta E=1.4$). When the color change between baseline and week 2 was examined by application, statistically different results were found between bleaching, lemon juice and DW ($p=0.0082$). The magnitude of color change was as follows: bleaching ($\Delta E=2.4$) > lemon juice ($\Delta E=1.8$) > DW ($\Delta E=1.2$) (Table 3).

When the color change between baseline and week 2 was exam-

Table 2. ANOVA results of the first application

	Variable	SS	MS	F value	ProbF	Cohend
Baseline-2 weeks (First application)	Material	22.259	7.420	5.444	0.002	0.953
	First application	19.038	9.519	6.984	0.002	0.881
	Material-First application	30.883	5.147	3.776	0.003	1.122

SS: Sum of squares, MS: Mean squares

Table 3. Bonferroni results of the first application

	Material			
	FC	NRC		p1- value
Baseline-2 weeks (First application)	1.4 (1.51)^{A}	2.2 (1.24)^{B}		0.0083
	First application			
	Bleaching	Lemon juice	DW	
Baseline-2 weeks (First application)	2.4 (2.01)^{A}	1.8 (0.83)^{B}	1.2 (0.94)^{C}	0.0082

[1] ANOVA F test p value; same superscript capital letters indicate no significant difference in rows. FC: Feldspathic ceramic, NRC: Nanohybrid resin composite, DW: Distilled water

ined by material-first application, the results obtained with bleaching and DW for FC were statistically different from those obtained with lemon juice (p=0.0084). The magnitude of color change was lemon juice (ΔE=1.9) > bleaching (ΔE=1.8) > DW (ΔE=0.4). For NRC, the results obtained with lemon juice and DW were statistically different from those obtained with bleaching (p<0.0112). The magnitude of color change was bleaching (ΔE=2.9) > DW (ΔE=2.0) > lemon juice (ΔE=1.6). For DIS, the results obtained with FC (ΔE=0.4) were statistically different from those obtained with NRC (ΔE=2.0) (p<0.0001) (Table 4).

The results of 2-way ANOVA test including the entire first and second applications are shown in Table 5. According to the results, the effect of the material on color between baseline-day 12 of the second application, baseline-day 24 of the second application, start of the second application-day 12 of the second application and start of the second application-day 24 of the second application was statistically significant (p<0.05).

Bonferroni results including the entire first and second applications are shown in Table 6. When examining the SAM group, between baseline-day 12 of the second application, the color change in the FC1 group (ΔE=1.2) was statistically different from NRC1 (ΔE=3.4) (p<0.0001). Between baseline-day 24 of the second application, the color change in the FC1 group (ΔE=1.7) was statistically different from NRC1 (ΔE=2.9) (p=0.0017). Between the start of the second application-day 12 of the second application, the color change in the FC1 group (ΔE=1.0) was statistically different from NRC1 (ΔE=2.1) (p=0.0057).

When examining the APFSAM group, between baseline-day 12 of the second application, the color change in the FC2 group (ΔE=1.5) was statistically different from NRC2 (ΔE=2.9) (p=0.0088). Between the start of the second application-day 12 of the second application, the color change in the FC2 group (ΔE=0.5) was statistically different from NRC2 (ΔE=2.0) (p=0.0002).

When all SAM and APFSAM groups were examined regardless of the material, the highest color change was found in the SAM group between baseline-day 12 of the second application (p<0.0001) and between baseline-day 24 of the second application (p=0.0017) and in the APFSAM group between baseline- day 24 of the second application (p>0.05) (ΔE=2.3). The lowest color change was found in the APFSAM group between start of the second application-day 12 of the second application (ΔE=1.2) (p>0.05).

Discussion

In this study, the null hypothesis that there would be no color change in specimens immersed in lemon juice, applied bleaching, immersed in black elderberry beverage or immersed in black elderberry beverage after APF application was partially rejected. APF application before the beverage with black elderberry had no effect on the color change induced by the beverage with black elderberry. All other applications and beverages were effective in color change of dental restorative materials.

There is no consensus on the thresholds of clinical perceptibility (PT) and acceptability (AT). Bona et al.[19] reported appropriate PT/AT values of 1.7/3.5 for ceramics of 1, 2 and 3 mm thickness. Dietschi et al.[20] used a value of 1.1 (between 0.7 and 1.7) for PT and 3.3 (between 2.6 and 3.8) for AT in their study on RCs. Based on the above studies, a PT/AT value of 1.2/3.5 was chosen in this study.

Although the CIEDE2000 formula has been shown to be a reliable indicator of the perceptibility and acceptability of color differences, most studies have used the CIELAB formula.[21] In a comprehensive study, Rashid et al.[22] reported that the CIELAB color difference formula was still used at present and found that this formula was used in 42% of the studies they examined. Tanthanuch et al.[23] reported that CIELAB was able to determine even the smallest color change and was advantageous in studies where reproducibility was critical. Therefore, the CIELAB formula was used in this study.

According to the results in terms of material in the first application, NRC had a higher color change than FC, but the magnitude of the change was clinically acceptable. According to the results in terms of application, the magnitude of the color change was bleaching > lemon juice > DW, but the magnitude of the change was clinically acceptable. For the material-application pair, the highest color change was observed for NRC-bleaching and the lowest for FC-DW. In none of the pairs did the color change increase to a clinically unacceptable level, but only FC-DW remained below the clinically detectable level.

Materials immersed in water or saliva may change color due to aging.[24] In this study, similar to the findings of Alharbi et al.[25], clinically perceptible color change was observed in specimens stored in DW, and only the color change with FC-DW was below the clinically perceptible level.

The acidic pH of beverages is a factor that increases the color change that occurs on the surface of restorative materials. The binding of anions to hydrogen ions in acids can lead to an increase in roughness and subsequent color change. The magnitude of the effect depends on the material and beverage, the acid concentration and the application time.[3] In their study on ceramics, Santos et al.[26] reported that orange juice, which has a higher pH than cola, causes less color change, while cola contains carbonic and phosphoric acid, in contrast, citric acid, which causes stronger color change, is found in acidic fruit juices.

The effect of acidic beverages on dental ceramics is due to the selective extraction of alkaline metal ions with low stabilization in the glass matrix. In a study by Çelakıl et al.[27] on the effect of acidic beverages on ceramics, lemon juice was found to increase the amount of degradation on the porcelain surface due to its low pH. In this study, lemon juice caused clinically perceptible color changes in both RC and FCs, which can be explained by the surface degrading property of acid, based on the above studies.

Bleaching agents can affect the color of restorative materials. It

Table 4. Bonferroni results of material-first application

		First application			
		Bleaching	Lemon juice	DW	p1- value
Baseline-2 weeks (First application)	FC	1.8 (2.30)^{A}	1.9 (0.52)^{B}	0.4 (0.23)^{A}	0.0084
	NRC	2.9 (1.55)^{A}	1.6 (1.05)^{B}	2.0 (0.59)^{B}	0.0112
p- value		0.1384	0.3252	<0.0001	

[1] ANOVA F test p value; same superscript capital letters indicate no significant difference in rows. FC: Feldspathic ceramic, NRC: Nanohybrid resin composite, DW: Distilled water

Table 5. ANOVA results of entire first and second applications

	Variable	**SS**	**MS**	**F value**	**ProbF**	**Cohend**
Baseline – day 12 of the second application	Material	65.091	65.091	35.068	0.000	1.324
	Application	0.209	0.209	0.112	0.738	0.075
	Material - Application	3.406	3.406	1.835	0.179	0.303
Baseline – day 24 of the second application	Material	11.427	11.427	6.023	0.016	0.549
	Application	0.002	0.002	0.001	0.973	0.007
	Material - Application	3.660	3.660	1.929	0.169	0.311
Start of the second application– day 12 of the second application	Material	35.895	35.895	24.884	0.000	1.115
	Application	2.008	2.008	1.392	0.242	0.264
	Material - Application	0.715	0.715	0.496	0.483	0.157
Start of the second application– day 24 of the second application	Material	6.521	6.521	4.900	0.030	0.495
	Application	0.549	0.549	0.412	0.523	0.144
	Material - Application	0.207	0.207	0.156	0.694	0.088

SS: Sum of squares, MS: Mean squares

Table 6. Bonferroni results of entire first and second applications

		Material			
		FC1	NRC1	Total	p1- value
SAM group	Baseline- Day 12 of the second application	1.2(0.96)^{A}	3.4(1.19)^{B}	2.3(1.53)	<0.0001
	Baseline- Day 24 of the second application	1.7 (1.19)^{A}	2.9 (1.03)^{B}	2.3 (1.24)	0.0017
	Start of the second application- day 12 of the second application	1.0 (0.72)^{A}	2.1(1.61)^{B}	1.5(1.35)	0.0057
	Start of the second application- day 24 of the second application	1.1(0.99)	1.8 (1.45)	1.5(1.27)	0.0946
		FC2	NRC2	Total	
APFSAM group	Baseline- Day 12 of the second application	1.5(1.99)^{A}	2.9 (1.07)^{B}	2.2 (1.72)	0.0088
	Baseline- Day 24 of the second application	2.2 (2.04)	2.5 (0.99)	2.3 (1.59)	0.5207
	Start of the second application- day 12 of the second application	0.5 (0.30)^{A}	2.0 (1.61)^{B}	1.2 (1.37)	0.0002
	Start of the second application- day 24 of the second application	1.1 (0.87)	1.5 (1.21)	1.3 (1.07)	0.1681

[1] ANOVA F test p value; same superscript capital letters indicate no significant difference in rows. SAM group: Immersion in immune-boosting beverage with black elderberry, APFSAM group: Immersion in immune-boosting beverage with black elderberry after acidulated phosphate fluoride, FC: Feldspathic ceramic, NRC: Nanohybrid resin composite

is thought that free radicals released by the oxidation reaction in an alkaline environment destroy chromogens, creating a tooth surface with more transparent molecules that reflect light less. The magnitude of the effect of the bleaching agent depends on the material structure, application time and concentration.[6] Tinastepe et al.[17] used FC, polymer-infiltrated ceramic-network, resin-nano and lithium disilicate ceramics and found that FCs were less affected by bleaching than resin-containing materials.

In this study, NRCs were obtained by polymerizing the material in a mould, but FCs are available in pre-prepared blocks. NRCs prepared manually in the laboratory or clinic may not achieve complete polymerization due to contact with oxygen. This increases the possibility of the material being affected by the external environment.[28] In a study by Öztürk et al.[6] using RC and resin-nanoceramics, it was reported that the resin content of the material and the method of preparation affected the color change.

According to the analysis of the entire first and second applications showed a clinically perceptible color change in the NRC1 group at 12 and 24 days, whereas color changes in the FC1 group were below the clinically perceptible level. Similarly, clinically perceptible color changes were observed in NRC2 group at 12 and 24 days, while color changes in FC2 group were below clinically perceptible levels. When the results obtained after exposure to the entire first and second applications were evaluated, NRC1 group was the most affected by the whole process. While the magnitude of color change in all other groups did not increase to clinically unacceptable levels, they remained at clinically perceptible levels.

There are studies reporting that APF gel caused surface roughness and color change in the materials and there are also studies reporting the opposite.[11,29] In this study, APF did not cause a significant color change in the materials. APF gel has an acidic character that allows water to bind to the organic matrix and exert a plasticizing effect on the resin, resulting in less surface roughness. In the study by Hosoya et al.[11], it has been reported that APF acid reduces the surface roughness by removing large particle fillers from the surface, and the possibility of being affected by external factors is reduced thanks to the small particle, supra nano-spherical fillers on the surface.

There are many studies investigating the effect of beverages on the color of restorative materials. These studies are mostly on tea, coffee, cola and wine.[1,12] The number of studies on the effect of immune-boosting beverages with black elderberry, whose consumption has increased since the COVID-19 pandemic due to its antiviral properties, on the color of dental restorative materials is insufficient.[13] In this respect, this study is a first in the literature and the results may help clinicians to understand the potential changes in the color of restorative materials when such beverages are consumed.

In this study, at the end of the second application, clinically acceptable color change was found in NRC1 and NRC2 groups, whereas clinically unacceptable color change was found in FC1 and FC2 groups. It could be argued that the type of pigment in the beverage had an effect on the beverage with black elderberry to cause color change to an acceptable magnitude. It is also possible that the slightly acidic nature of the beverage provides a background that facilitates pigment retention over time. The results of this study were similar to those of Alharbi et al.[25] and Guler et al.[30] who concluded that colorants change the color of restorative materials.

Lemon juice or home bleaching does not seem to create a scenario that prevents the preference for FC or NRC, as they do not exceed the AT determined in this study. However, it could be reported that FC is a better alternative to NRC in terms of resistance to change in color. Similarly, the immune-boosting beverage is not a barrier to restoration with FC or NRC as it does not exceed the AT. However, individuals should be aware that beverages containing black elderberry as an immune booster, may change the color of dental restorations to a noticeable magnitude. There is no restriction on the use of APF gel, as prior application of APF will not significantly alter the color change caused by the immune-boosting beverage. It may be useful for dentists to inform individuals that color change may occur in ceramic or RC restorations due to home bleaching agents, lemon juice, immune-boosting beverages with black elderberry, but that this color change will remain at an acceptable level and that oral care should be taken to minimize color change as much as possible.

The limitation of this study is that it was conducted in an in vitro environment. The complexity of the oral cavity environment, including the buffering system of saliva, the pH of the oral cavity, the dilution effect of acidic foods and beverages, microbial film formation and the mechanical effect of chewing and other similar forces were not taken into account. Future in vitro and in vivo studies are needed to investigate the effect on dental restorative materials of home bleaching, acidic beverages or immune-boosting beverages which have increased in consumption since the COVID-19 pandemic.

Conclusion

The results within the limitations of this study are as follows:

- At the end of the first application, both FC and NRC, regardless of home bleaching and lemon juice immersion, showed a color change that did not exceed the clinical acceptability threshold established in this study.
- At the end of the first application, both home bleaching and lemon juice immersion, regardless of the FC and NRC materials, were found to cause color changes that did not exceed the clinical acceptability threshold determined in this study.
- At the end of the second application, both FC and NRC specimens immersed in immune-boosting beverage and FC and NRC specimens immersed in immune-boosting beverage after APF were found to have a tendency for color change of a magnitude not exceeding the clinical acceptability threshold established in this study.

Ethical Approval

Since present study was an in vitro study in which humans and animals, including material/data, were not used for experimental purposes, ethical approval was not required.

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Author Contributions

Methodology : K.Y.
Project Administration : F.G.
Validation : F.G.
Preparation of Specimens : K.Y.
Performing the Tests : K.Y.
Writing the Manuscript : K.Y.
Writing the References : F.G.

Conflict of Interest

The authors declare no conflicts of interest.

Authors' ORCID(s)

K.Y. 0000-0002-2974-6696
F.G. 0000-0002-4009-3972

References

1. Garoushi S, Lassila L, Hatem M, Shembesh M, Baady L, Salim Z, et al. Influence of staining solutions and whitening procedures on discoloration of hybrid composite resins. Acta Odontol Scand. 2013;71(1):144–50. doi:10.3109/00016357.2011.654253.
2. Thomas PA, Krishnamoorthi D, Mohan J, Raju R, Rajajayam S, Venkatesan S. Digital Smile Design. J Pharm Bioallied Sci. 2022;14(Suppl 1):S43–s49. doi:10.4103/jpbs.jpbs_164_22.
3. Rathod A, Vadavadagi SV, Verma T, Kumar P, Deepak PV, Deb S, et al. Effect of Acidic Beverages on Color Stability and Microhardness of Various Esthetic Restorative Materials: A Comparative Study. J Pharm Bioallied Sci. 2021;13(Suppl 2):S1084–s1087. doi:10.4103/jpbs.jpbs_189_21.
4. Labban N, Al Amri MD, Alnafaiy SM, Alhijji SM, Alenizy MA, Iskandar M, et al. Influence of Toothbrush Abrasion and Surface Treatments on Roughness and Gloss of Polymer-Infiltrated Ceramics. Polymers (Basel). 2021;13(21). doi:10.3390/polym13213694.
5. Alnasser M, Finkelman M, Papathanasiou A, Suzuki M, Ghaffari R, Ali A. Effect of acidic pH on surface roughness of esthetic dental materials. J Prosthet Dent. 2019;122(6):567.e1–567.e8. doi:10.1016/j.prosdent.2019.08.022.
6. Öztürk C, Çelik E, Özden AN. Influence of bleaching agents on the color change and translucency of resin matrix ceramics. J Esthet Restor Dent. 2020;32(5):530–535. doi:10.1111/jerd.12580.
7. Peng PW, Huang CF, Hsu CY, Chen A, Ng HH, Cheng MS, et al. Color Stability and Staining Susceptibility of Direct Resin-Based Composites after Light-Activated In-Office Bleaching. Polymers (Basel). 2021;13(17). doi:10.3390/polym13172941.
8. Belevcikli M, Kılıç G, Çakır E. Fluorid jel uygulama süresinin fissür örtücülerin yüzey pürüzlülüğüne etkisi. Journal of International Dental Sciences (Uluslararası Diş Hekimliği Bilimleri Dergisi). 2023;8(3):92–97.
9. Tanoue N, Soeno K, Kawasaki K, Atsuta M. Influence of acidulated phosphate fluoride solution on the color stability of indirect composites. J Prosthet Dent. 2004;92(4):343–7. doi:10.1016/j.prosdent.2004.07.008.
10. Singh K, Jhingan P, Malik M, Mathur S. In vitro comparative evaluation of physical and chemical properties of surface enamel after using APF and SDF with or without laser activation. Eur Arch Paediatr Dent. 2023;24(4):461–472. doi:10.1007/s40368-023-00808-z.
11. Hosoya Y, Shiraishi T, Puppin-Rontani RM, Powers JM. Effects of acidulated phosphate fluoride gel application on surface roughness, gloss and colour of different type resin composites. J Dent. 2011;39(10):700–6. doi:10.1016/j.jdent.2011.08.002.
12. Al-Angari SS, Meaigel S, Almayouf N, Quwayhis S, Aldahash A, Al-Angari NS. The Effects of a coffee beverage and whitening systems on surface roughness and gloss of CAD/CAM lithium disilicate glass ceramics. J Appl Biomater Funct Mater. 2021;19:22808000211058866. doi:10.1177/22808000211058866.
13. Yılmaz K, Özdemir E, Gönüldaş F. Effect of immune-boosting beverage, energy beverage, hydrogen peroxide superior, polishing methods and fine-grained dental prophylaxis paste on color of CAD-CAM restorative materials. BMC Oral Health. 2024;24(1):1104. doi:10.1186/s12903-024-04895-2.
14. Nascimento Oliveira AL, Elias CN, Salomão Dos Santos HE, Dos Santos C, de Biasi RS. Physical Properties and Color Stainability by Coffee and Red Wine of Opaque and High Translucency Zirconia Dental Ceramics after Hydrothermal Degradation. Int J Biomater. 2022;2022:1571729. doi:10.1155/2022/1571729.
15. Schneider LF, Mueller B, Nisie Tango R, Volpato CAM. Effect of coffee staining and simulated oral hygiene methods on the color and translucency of a nanoceramic resin. J Esthet Restor Dent. 2024;36(7):1020–1028. doi:10.1111/jerd.13214.
16. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J. 2006;25(2):371–6. doi:10.4012/dmj.25.371.
17. Tinastepe N, Malkondu O, Iscan I, Kazazoglu E. Effect of home and over the contour bleaching on stainability of CAD/CAM esthetic restorative materials. J Esthet Restor Dent. 2021;33(2):303–313. doi:10.1111/jerd.12604.
18. Shokry TE, Shen C, Elhosary MM, Elkhodary AM. Effect of core and veneer thicknesses on the color parameters of two all-ceramic systems. J Prosthet Dent. 2006;95(2):124–9. doi:10.1016/j.prosdent.2005.12.001.
19. Della Bona A, Pecho OE, Ghinea R, Cardona JC, Pérez MM. Colour parameters and shade correspondence of CAD-CAM ceramic systems. J Dent. 2015;43(6):726–34. doi:10.1016/j.jdent.2015.02.015.
20. Dietschi D, Abdelaziz M, Krejci I, Di Bella E, Ardu S. A novel evaluation method for optical integration of class IV composite restorations. Aust Dent J. 2012;57(4):446–52. doi:10.1111/adj.12001.
21. Hardan L, Bourgi R, Hernández-Escamilla T, Piva E, Devoto W, Lukomska-Szymanska M, et al. Color stability of dual-cured and light-cured resin cements: A systematic review and meta-analysis of in vitro studies. J Prosthodont. 2024;33(3):212–220. doi:10.1111/jopr.13757.
22. Rashid F, Farook TH, Dudley J. Digital Shade Matching in Dentistry: A Systematic Review. Dent J (Basel). 2023;11(11). doi:10.3390/dj11110250.
23. Tanthanuch S, Kukiattrakoon B, Thongsroi T, Saesaw P, Pongpaiboon N, Saewong S. In vitro surface and color changes of tooth-colored restorative materials after sport and energy drink cyclic immersions. BMC Oral Health. 2022;22(1):578. doi:10.1186/s12903-022-02624-1.
24. Ferracane JL. Resin composite–state of the art. Dent Mater. 2011;27(1):29–38. doi:10.1016/j.dental.2010.10.020.
25. Alharbi A, Ardu S, Bortolotto T, Krejci I. In-office bleaching efficacy on stain removal from CAD/CAM and direct resin composite materials. J Esthet Restor Dent. 2018;30(1):51–58. doi:10.1111/jerd.12344.
26. Dos Santos DM, da Silva EVF, Watanabe D, Bitencourt SB, Guiotti AM, Goiato MC. Effect of different acidic solutions on the optical behavior of lithium disilicate ceramics. J Prosthet Dent. 2017;118(3):430–436. doi:10.1016/j.prosdent.2016.10.023.
27. Çelakıl T, Evlioğlu G. Asidik maddelerin farklı dental porselenlerin yüzey özellikleri ve iyon çözünürlüğü üzerindeki etkinliğinin değerlendirilmesi. Ege Üniversitesi Diş Hekimliği Fakültesi. 2020;41(2):99–111.
28. Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: state of the art. J Prosthodont Res. 2014;58(4):208–16. doi:10.1016/j.jpor.2014.07.003.
29. Bayrak GD, Dosdoğru EY, Öztürk D, Yıldırım Y, Kuvvetli SS. The effect of surface coating agent on the surface roughness of restorative materials exposed to acidulated phosphate fluoride. Atatürk Üniversitesi Diş Hekimliği Fakültesi Dergisi. 2020;30(4):557–563. doi:10.17567/ATAUNIDFD.743955.
30. Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stainability of resin composite provisional restorative materials. J Prosthet Dent. 2005;94(2):118–24. doi:10.1016/j.prosdent.2005.05.004.