

Does the temperature of beverages affect the surface roughness, hardness, and color stability of a composite resin?

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ABSTRACT

Objective: To investigate the effect of beverages' temperature on the surface roughness, hardness, and color stability of a composite resin. **Materials and Methods:** Fifty specimens of the Filtek Z250 composite (3M ESPE, Dental Products, St.Paul, MN, USA) were prepared and initial roughness, microhardness, and color were measured. Then the specimens were randomly divided into five groups of 10 specimens each: Coffee at 70°C, coffee at 37°C, cola at 10°C, cola at 37°C, and artificial saliva (control). After the samples were subjected to 15 min × 3 cycles per day of exposure to the solutions for 30 days, the final measurements were recorded. **Results:** After immersion in beverages, the artificial saliva group showed hardness values higher than those of the other groups ($P < 0.001$) and the microhardness values were significantly different from the initial values in all groups except for the control group. Both cola groups showed roughness values higher than the baseline values ($P < 0.05$), while the other groups showed values similar to the baseline measurements. When ΔE measurements were examined, the 70°C coffee group showed the highest color change among all the groups ($P < 0.05$). **Conclusion:** High-temperature solutions caused alterations in certain properties of composites, such as increased color change, although they did not affect the hardness or roughness of the composite resin material tested.

Key words: Color stability, different beverages, different temperature, microhardness, surface roughness

INTRODUCTION

Resin composites are one of the most popular materials in aesthetic dentistry because of their excellent aesthetic properties, adequate strength, and their ability to be bonded to dentin or enamel. The popularity of composite resins can be attributed to demands from patients for tooth-colored restorations.^[1]

Aesthetic restorative materials should mimic the appearance of natural teeth.^[2] An aesthetic restoration with an unacceptable color is the main cause for replacement of restorations.^[3] Surface texture and

gloss are also important characteristics of aesthetic restorations that determine their aesthetic effect.^[4,5]

In modern societies, diet includes a wide range of colored foods and beverages. Surface staining of a composite is mainly related to the absorption or adsorption of these coloring substances.^[6-8] In addition to color alteration, some substances can also affect several surface properties of composite resins, such as microhardness^[9] and roughness,^[10] and cause more staining.

The durability of restorative materials in the

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mouth is related to their resistance to dissolution and disintegration. It has been demonstrated in several studies that the erosive activity of acids as ingredients of beverages and foodstuffs in diet affects the microhardness, wear, and water sorption of the composite resin and durability of the restoration in the long term.^[11-14]

While applying a composite, one of the major objectives is to obtain restorations with smooth surfaces, without porosity, resulting in better aesthetics. Roughness is an important property of the restoration surface, as a rough surface enhances accumulation of dental plaque and residues, which causes gingival irritation and secondary caries risk. It also diminishes the gloss of the restoration and causes more discoloration or surface degradation.^[15]

When restorative materials are placed in the oral environment, they are constantly subjected to thermal changes due to the intake of beverages and foods at different temperatures. These temperature changes can have an unfavorable effect on the margins of the restorations.^[16] Several studies have been conducted to determine the effects of different staining solutions on the surface characteristics of composite resins,^[9,17,18] but to the best of our knowledge, no study has evaluated the effect of solutions' temperature on these properties. Thus, the aim of the present study was to evaluate the effect of beverages' temperature on the surface roughness, hardness, and color stability of a hybrid composite resin. The tested hypothesis was that the temperature of beverages has no effect on the color stability, surface roughness, or hardness of the composite resin.

MATERIALS AND METHODS

Specimen preparation

A microhybrid resin composite (Filtek Z250, shade A3, lot 9WY, 3M ESPE, St. Paul, MN, USA) was selected for this study. A total of 50 cylindrical samples of Filtek Z250 were packed into a Teflon ring mold (12 mm in diameter and 2 mm in thickness). A Mylar strip was placed on a glass slab, and then the mold was filled and another Mylar strip and glass slab were laid on top of the specimen surface. The composite specimens were cured with an Light Emitting Diode device (Elipar Freelight 2, 3M ESPE, St. Paul, USA) through glass slides on both sides of the mold for 20 s each, according to the manufacturer's instructions. The LED curing light was calibrated before and after each curing to ensure that all samples were cured with approximately the same intensity

of light (1250 mW/cm²). The intensity of light was frequently monitored by means of a radiometer. The specimens were stored in 37°C distilled water for 24 h before finishing and polishing in order to replicate the oral conditions following polymerization.^[19] The specimens were polished with Sof-Lex aluminum oxide polishing disks (3M ESPE, Dental Products, Seefeld, Germany), starting with coarse and ending with extra fine. Polishing procedures were kept to a minimum time, 10 s for each step, to avoid micro-crack formation.^[20] Subsequently, baseline color, surface roughness, and microhardness values were measured.

The composite specimens were randomly subdivided into five groups of 10 specimens each; the control group was maintained in artificial saliva and the four experimental groups were submitted to cycling in selected beverages [Table 1].

Group 1 : Specimens were stored in artificial (control) saliva at 37°C in an incubator (EN 120 incubator; Nüve, Ankara, Turkey). The composition of the artificial saliva was 1.5 mmol/l Ca (NO₃)₂·H₂O, 0.9 mmol/l Na₂HPO₄·2H₂O, 150 mmol/l KCl, 0.1 mol/l H₂NC(CH₂OH)₃ (TRIS), and 0.05 NaF.^[21]

Group 2 : Specimens were stored in 10°C cola in a refrigerator (Arcelik 4252N; Arcelik A.S. Istanbul, Turkey). A new bottle of cola was used in each period to maintain an acceptable level of carbonic gas.

Group 3 : Specimens were stored in 37°C cola and held in a water bath at 37°C. A new bottle of cola was used in each test period.

Group 4 : Specimens were stored in 70°C coffee solution, which was prepared with 2.8 g of coffee, weighed using a sensitive balance (1620c sensitive balance; Precisa, Zurich, Switzerland), added to 150 ml of boiling distilled water and held in a water bath at 70°C (OLS 200; Grant Instruments Ltd, Cambridge, England). Coffee solution was freshly prepared before each period.

Group 5 : Coffee solution was prepared as described for group 4 and cooled to 37°C. Specimens were stored in this solution and held in a water bath at 37°C (OLS 200; Grant Instruments Cambridge, England).

Specimens were immersed in the test solutions for 15 min three times a day (morning, afternoon, and

Table 1: Beverages used in the study

Beverage	pH	Manufacturer
Artificial saliva	7.0	-
Coca Cola 10°C	2.72	Coca-Cola®, Refrescos Ipiranga, Ribeirão Preto, SP, Brazil
Coca Cola 37°C	2.48	
Nescafe classic 70°C	4.85	Nestle Suisse SA, Vevey, Switzerland
Nescafe classic 37°C	5.04	

night) for 30 days. The specimens were kept immersed in 1.2 ml of artificial saliva at 37°C in an incubator (EN 120 incubator; Nüve) in the intervals between cycles. All specimens were stored in light-proof containers and the solutions were changed for each test period. The temperatures were measured with a digital thermometer. After 30 days of immersion in the solutions, the specimens were rinsed with distilled water for 5 min and blotted dry with absorbent paper before the final measurements.

The pH values of beverages at different temperatures were measured using a pH meter (HI 221; Hanna Instruments, Cluj-Napoca, Romania). The pH value was 4.85 for 70°C coffee, 5.04 for 37°C coffee, 2.72 for 10°C cola, and 2.48 for 37°C cola.

Color measurements

The color of specimens was measured at baseline and after 30 days immersion using a VITA Easyshade (Vident, Brea, CA, USA) spectrophotometer, with the CIELAB scale L^* , a^* , and b^* . ΔE^* was calculated by the following equation:

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

All color measurements were performed three times for each specimen. The device was calibrated before the measurement of each specimen.

Surface roughness measurements

All the specimens were subjected to roughness testing using a contact profilometer (Surfcorder SE 1700; Kosaka Corp., Tokyo, Japan) equipped with a 5-mm-radius diamond-tipped stylus that was attached to a pickup head. The stylus traversed the surface of the specimen at a constant speed of 0.5 mm/s with a force of 4 mN and automatic return. Each specimen was traced in four parallel locations near the center across the finished and/or polished surface with an evaluation length of 4 mm. Five measurements in different directions were recorded for each specimen. Leveling of all parts of the apparatus was achieved by adjusting the pickup head knob. A calibration block

was used periodically to check the performance of the device.

Vickers hardness measurements

A Vickers surface microhardness device (HMV 2000; Shimadzu, Kyoto, Japan) was used for specimen indentation. For each microhardness test, five indentations with 50 g load for 15 s (100 μ m of distance) were performed for each specimen.

All color, surface roughness, and microhardness measurements were performed by the same operator, and the mean values were used for the subsequent statistical analysis.

Statistical analysis

The data among groups and the changes over time were evaluated by using analysis of variance (ANOVA) for repeated measures for the parameters of microhardness, roughness, and color (L , a , b) and processed with SPSS (version 15.0.1; SPSS, Chicago, IL, USA). A P value of < 0.05 was considered statistically significant. Multiple comparisons were evaluated by Bonferroni test. Welch ANOVA test was used to evaluate the differences in ΔE measurements among the groups. Multiple comparisons were evaluated using the Games-Howell test. A P value of < 0.05 was considered statistically significant.

RESULTS

Microhardness change

In Table 2, means, standard deviations (\pm), and statistically significant differences in microhardness change of the tested composite resin for each beverage are presented. There were no statistically significant differences among the baseline hardness values of the tested composite resin ($P > 0.05$). After immersion in beverages, the artificial saliva group showed hardness values higher than those of the other groups ($P < 0.05$) and the hardness values of the composite resin were similar among the cola and coffee groups ($P > 0.05$). The 37°C cola group showed the greatest microhardness alteration (ΔV). At the end of the experiment, the ΔV values of the cola groups and the 70°C coffee group were significantly higher than those of the artificial saliva (control) and 37°C coffee group ($P < 0.05$).

Surface roughness change

The means, standard deviations (\pm), and statistically significant differences in surface roughness change of the tested composite resin in different beverages are shown in Table 3. While the 10°C and 37°C cola

groups showed roughness values higher than the baseline values ($P < 0.05$), the coffee groups and the control group showed roughness values similar to the baseline measurements. No significant differences were found among the groups regarding the baseline measurements and measurements after immersion in beverages ($P > 0.05$). ΔRa values of all groups were statistically similar at the end of the experimental period.

Color change

Table 4 shows the means, standard deviations (\pm), and statistically significant differences in color change in the tested composite resin after immersion in different beverages. No significant differences were observed in the baseline color measurements (L , a , b) of the tested composite resin among the test groups ($P > 0.05$). After immersion in beverages, the 70°C coffee and 37°C coffee groups showed L values lower than those of the other groups ($P < 0.05$). Moreover, the 70°C

coffee group showed an L value significantly lower than that of the 37°C coffee group ($P < 0.05$). When a and b values were compared among the groups, all groups showed similar values after immersion in beverages ($P > 0.05$), except for the 70°C coffee group, which showed a and b values higher than the others ($P < 0.05$). When the baseline values and values after immersion in beverages were compared in each beverage group, the 70°C coffee and 37°C coffee groups showed L values lower than baseline ($P < 0.05$) and the 70°C coffee group showed a value higher than baseline ($P < 0.05$). When b values were compared, all groups showed values higher than baseline ($P < 0.05$).

The analysis of ΔE measurements revealed that the 70°C coffee group showed the highest color change ($P < 0.05$). The artificial saliva and 10°C cola groups showed similar color change to each other ($P > 0.05$), but the color change was lower than that of the other groups ($P < 0.05$).

Table 2: Means (standard deviations) for surface hardness of tested composite resin

Groups	Baseline (V1)	After immersion (V2)	P	ΔV
Artificial saliva 37°C	101.6 \pm 14.2 ^{A,a}	97.1 \pm 10.4 ^{A,a}	0.319	4.52 \pm 12.54 ^a
Cola 10°C	100.6 \pm 10.7 ^{A,a}	77.9 \pm 7.9 ^{B,b}	<0.001	22.74 \pm 11.71 ^b
Cola 37°C	112.5 \pm 15 ^{A,a}	79.7 \pm 5.3 ^{B,b}	<0.001	32.83 \pm 16.81 ^b
Coffee 70°C	100 \pm 15.7 ^{A,a}	77.3 \pm 3.2 ^{B,b}	<0.001	22.78 \pm 16.86 ^b
Coffee 37°C	94.9 \pm 8.5 ^{A,a}	77.7 \pm 6.9 ^{B,b}	<0.001	17.18 \pm 12.11 ^a
P	0.061	<0.001		0.001

Different uppercase letters in rows and lowercase letters in columns indicate statistically significant difference

Table 3: Means (standard deviations) for surface roughness of tested composite resin (μm)

Groups	Baseline (Ra1)	After immersion (Ra2)	P	ΔRa
Artificial saliva 37°C	0.12 \pm 0.02 ^{A,a}	0.12 \pm 0.03 ^{A,a}	0.820	0 \pm 0.01 ^a
Cola 10°C	0.13 \pm 0.03 ^{A,a}	0.16 \pm 0.04 ^{B,a}	0.001	-0.03 \pm 0.02 ^a
Cola 37°C	0.13 \pm 0.02 ^{A,a}	0.16 \pm 0.04 ^{B,a}	0.005	-0.03 \pm 0.03 ^a
Coffee 70°C	0.12 \pm 0.02 ^{A,a}	0.13 \pm 0.03 ^{A,a}	0.611	0 \pm 0.03 ^a
Coffee 37°C	0.13 \pm 0.04 ^{A,a}	0.14 \pm 0.03 ^{A,a}	0.145	-0.01 \pm 0.04 ^a
P	0.893	0.124		0.059

Different uppercase letters in rows and lowercase letters in columns indicate statistically significant difference

Table 4: Means (standard deviations) for color measurements of tested composite resin

Groups	L			a			b			ΔE
	Baseline	After immersion in beverages	P	Baseline	After immersion in beverages	P	Baseline	After immersion in beverages	P	
Artificial saliva 37°C	73.9 \pm 0.6 ^{a,A}	74 \pm 0.6 ^{a,A}	0.897	-0.32 \pm 0.39 ^{a,A}	-0.1 \pm 0.5 ^{a,A}	0.522	20.1 \pm 1 ^{a,A}	21.7 \pm 1.2 ^{b,A}	<0.001	1.91 \pm 0.67 ^A
Cola 10°C	73.6 \pm 1.2 ^{a,A}	73.8 \pm 1.3 ^{a,A}	0.553	0.17 \pm 0.37 ^{a,A}	0.57 \pm 0.5 ^{a,A}	0.247	19.8 \pm 0.5 ^{a,A}	21.8 \pm 0.9 ^{b,A}	<0.001	2.11 \pm 0.69 ^A
Cola 37°C	74.1 \pm 0.8 ^{a,A}	74.7 \pm 1 ^{a,A}	0.132	-0.26 \pm 0.44 ^{a,A}	0.22 \pm 0.62 ^{a,A}	0.166	19.9 \pm 1.2 ^{a,A}	22.3 \pm 1.5 ^{b,A}	<0.001	2.65 \pm 0.74 ^B
Coffee 70°C	73.6 \pm 1 ^{a,A}	62.2 \pm 2.7 ^{b,B}	<0.001	-0.64 \pm 2.27 ^{a,A}	2.93 \pm 0.91 ^{b,B}	<0.001	19.8 \pm 1.5 ^{a,A}	28.0 \pm 1.6 ^{b,B}	<0.001	14.67 \pm 2.47 ^C
Coffee 37°C	73.4 \pm 0.5 ^{a,A}	71.1 \pm 1.1 ^{b,C}	<0.001	-0.35 \pm 0.14 ^{a,A}	0.28 \pm 0.27 ^{a,A}	0.071	20.4 \pm 0.6 ^{a,A}	23.4 \pm 1 ^{b,A}	<0.001	3.86 \pm 1.25 ^B
P	0.352	<0.001		0.564	<0.001		0.610	<0.001		<0.001

Different lowercase letters in rows and uppercase letters in columns indicate statistically significant difference

DISCUSSION

This study examined the influence of the temperature of beverages on the hardness, roughness, and color change of a microhybrid composite resin. Coffee and cola were selected in this study because they are very frequently consumed beverages. In the present study, composite resin was immersed in beverages at different temperatures. The temperatures of the coffee groups were 37°C and 70°C and of the cola groups were 37°C and 10°C.^[16,22]

The filler particles and the resin matrix of a composite and the characteristics of these particles have a direct impact on surface roughness, hardness, and susceptibility to staining. Filtek Z250 is a universal microhybrid composite resin with an organic matrix of bisphenol-glycidyl methacrylate, Bis-GMA, urethane dimethacrylate UDMA, and ethoxylated bisphenol A dimethacrylate, Bis-EMA. Its filler content consists of 60% zirconia/silica particles by volume, ranging from 0.01 to 3.5 µm. The presence of UDMA and Bis-EMA makes it more color stable and more hydrophobic.^[23]

Besides material composition, the finishing and polishing procedures may also influence the composite surface quality, and are therefore linked to discoloration of resin composites.^[24,25] In the present study, Soflex was used for all the specimens because it has been reported to give the smoothest surface for composite resins in previous studies.^[26,27]

Salivary enzymes, pH changes, organic solvents, and the ionic composition of food, beverages, or saliva may influence the surface quality of composite resins.^[28] In this study, specimens were immersed in coffee and cola for 3 × 15 min a day over a 30-day period in order to simulate clinical conditions. At all other times, specimens were stored in artificial saliva at 37°C.

As can be observed in Table 2, the artificial saliva group presented the highest level of microhardness, which is consistent with the literature.^[9,29] Coffee and cola caused more reduction of surface hardness of the tested composite resin than the artificial saliva did. The greatest reduction in microhardness was observed in the specimens immersed in 37°C cola, with the lowest pH. In low pH drinks, composite resins show a high solubility and that solubility causes surface erosion and dissolution, which will affect the wear and hardness of the materials.^[30,31] It has been shown that low pH media affect the chemical erosion of the hybrid materials by acid etching the surface and leaching the matrix-forming cations.^[32]

Although all cola and coffee groups showed reduced microhardness values, comparison of the groups immersed in cola and coffee solutions did not reveal any significant differences. This result is not consistent with the study by da Silva, *et al.* who reported that the microhardness of their material (nanoparticulated composite resin) did not change to a significant degree when immersed in coffee.^[13] The reduction in microhardness caused by coffee at 70°C was significantly higher than that caused by coffee at 37°C. Cola at 37°C produced more microhardness change than cola at 10°C did, but the difference was not statistically significant.

In the present study, however, both cola and coffee had low pH, only cola affected the roughness of the tested composite resin. The differences between baseline and after immersion in beverages roughness values of the cola groups were statistically significant. This may have been a result of the presence of acids and sugars in the chemical composition of the cola, which promote surface erosion of the composite resin. In addition, artificial saliva and coffee did not change the roughness of the composite resin to a statistically significant extent. This study's result is similar to that reported by Kitchens and Owens who found that surface roughness of enamel did not increase when immersed in coffee, but increased when immersed in cola.^[29] Conversely, da Silva *et al.* detected significant degradation of the resin matrix with immersion in coffee.^[13] They concluded that the consumption of coffee did not affect the composite resin's microhardness, but its surface roughness was altered in the analyzed period. Similarly, Dos Santos, *et al.* detected significant degradation of resin matrix upon immersion in coffee at high temperature.^[33] Different temperatures of the same immersion media (cola at 37-10°C, coffee at 37-70°C) did not affect the level of surface roughness change in the present study.

According to our study, immersion in artificial saliva promoted a slight color change ($\Delta E = 1.91$), classified as slightly perceptible. Similar results were observed by Omata, *et al.*^[23] and Domingos, *et al.*^[22]

The beverages used in this study caused varying degrees of discoloration in the tested composite resin. The highest discoloration ($\Delta E = 3.86-14.67$) was seen in the coffee groups, followed by the cola groups ($\Delta E = 2.11-2.65$). It has been reported in several studies that ΔE values ranging from 1 to 3 are perceptible to the naked eye^[34] and ΔE values greater than 3.3 are clinically unacceptable.^[35] Thus,

in the present study, immersion in coffee caused unacceptable color changes in the composite resin tested. Mundim, *et al.* also reported an unacceptable discoloration of Filtek Z250 when stored in coffee for 15 days.^[17] Discoloration by coffee was due to both absorption and adsorption of polar colorants onto the surface of materials. This adsorption and penetration of colorants into the organic phase of the materials was explained by the authors as probably due to the compatibility of the polymer phase with the yellow colorants of coffee.^[36] This may explain the discoloration of composite specimens observed after immersion in coffee.

In addition, our results showed that although cola had the lowest pH and that it might damage the surface integrity of resin composite materials, cola did not cause as much discoloration as coffee did, possibly due to its lack of yellow colorants.^[36] Further, the findings of previous studies also lent support to the present study in that coffee caused more discoloration than cola.^[7,17,37,38]

The higher temperature coffee caused more discoloration of the composite resin than coffee at 37°C did. This may have been due to the lower pH of coffee at 70°C. Villalta, *et al.* stated that low pH may indeed affect the surface integrity and promote an increase in susceptibility to staining.^[39] In agreement with this finding, in the present study, coffee at 70°C affected the resin surface more, decreased the surface hardness, and caused more staining.

The differences in results between the present study and previous studies were probably due to differences in methodology.^[13,33,40] Several studies have shown that a variety of factors such as chemical composition of the restorative material, type of immersion solution, immersion time, and polishing technique affect the results.^[8,22,37]

The literature has widely demonstrated the potential effects of certain beverages on composite resins' surface characteristics, but there is no report on whether or how the temperature of these beverages affects composite resins. Further studies would need to be conducted in order to give a more thorough understanding of the effects of beverages' temperature on composite resins' surface properties and to assure better color stability and long-term maintenance of restorations.

Within the limitations of this *in vitro* study, the tested hypothesis that the temperature of beverages has no

effect on the color stability, surface roughness, or hardness of the composite resin was rejected.

CONCLUSION

Based on the methodology employed and the results obtained, it may be concluded that:

- Temperature rise in beverages can cause alterations in certain properties of composites, such as increased color change and decreased microhardness, although it did not affect the roughness of the composite resin material tested.
- Cola was the beverage that most reduced the surface hardness of the composite resin tested.
- Coffee, especially at 70°C, caused more discoloration of the composite resin surface.
- Professionals may advise patients about the possible negative effects of these beverages, and to drink coffee warm and cola cold.

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