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ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

Evaluation of the Effect of Different Beverages on Microhardness of Single-Shade Universal Resin Composites

Farklı İçeceklerin Tek Renkli Üniversal Rezin Kompozitlerin Mikrosertliği Üzerine Etkilerinin İncelenmesi

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ÖZ

Amaç: Bu çalışmada farklı içeceklerin tek renkli üniversal rezin kompozitlerin mikrosertlik değerleri üzerindeki etkilerinin incelenmesi amaçlandı.

Gereç ve Yöntemler: Farklı üreticilere ait sekiz tek renkli üniversal rezin kompozitten (Admira Fusion X-tra, Voco; Charisma Diamond One, Kulzer; Charisma Topaz One, Kulzer; Essentia Universal, GC; Omnichroma, Tokuyama; Optishade, Kerr; Vittra APS Unique, FGM; Zenchroma, President Dental) toplam 432 disk şeklinde örnek (10x2 mm) hazırlandı. Örnekler, kontrol grubu olarak distile su (pH:7) ve deney grupları olarak kahve (pH:5), kırmızı şarap (pH:3.5), kola (pH:2.5), multivitamin (pH:3) ve yeşil çay (pH:6) içeceklerinde 6 aylık klinik kullanıma denk gelen sürede (37°C, 6 gün) bekletildi. Başlangıç (t_0), termal döngü (5-55°C, 5000 döngü) ve içecekte bekletme sonrası (t_1) Vickers mikrosertlik ölçümleri yapıldı. Elde edilen veriler ANOVA ve Bonferroni testi (p<0,05) ile analiz edildi.

Bulgular: Test edilen tek renkli üniversal rezin kompozitler ve içecekler arasında mikrosertlik değerleri açısından istatistiksel olarak anlamlı farklılıklar bulundu (p<0,001). Admira Fusion X-tra en yüksek mikrosertlik ortalama değerini gösterdi (74,3). Tüm içeceklerin mikrosertlik değerleri üzerinde anlamlı bir etkisi olduğu gözlendi (p<0,001). Kırmızı şarap test edilen kompozitlerin mikrosertlik değerlerinde en fazla değişime neden oldu. Kompozit tipi, içecek ve zaman arasındaki etkileşimler istatistiksel olarak anlamlı bulundu (p=0,001).

Sonuç: Asidik içecekler, tek renkli üniversal rezin kompozitlerin mikrosertlik değerlerinde belirgin düşüşlere neden oldu. Bu sonuçlara göre restoratif materyal seçiminde asidik içeceklere maruziyet göz önünde tutulmalıdır.

Anahtar Kelimeler: Asidik içecek, mikrosertlik, tek renkli üniversal rezin kompozit, termal döngü, Vickers.

ABSTRACT

Objective: The aim of this study was to investigate the effects of different beverages on the microhardness values of single-shade universal resin composites.

Materials and Methods: A total of 432 disk-shaped samples (10x2 mm) were prepared from eight single-shade universal resin composites produced by different manufacturers (Admira Fusion X-tra, Voco; Charisma Diamond One, Kulzer; Charisma Topaz One, Kulzer; Essentia Universal, GC; Omnichroma, Tokuyama; Optishade, Kerr; Vittra APS Unique, FGM; Zenchroma, President Dental). The samples were stored in distilled water (pH:7) as the control group and experimental groups were stored in coffee (pH:5), red wine (pH:3.5), coke (pH:2.5), multivitamin (pH:3), and green tea (pH:6) for a duration equivalent to 6 months of clinical use (37°C, 6 days). Vickers microhardness measurements were taken at the beginning (t_0), after thermal cycling (5-55°C, 5000 cycles), and following immersion in the beverages (t_1). The obtained data were analyzed using the Robust ANOVA and Bonferroni tests (p<0.05).

Results: There were statistically significant differences in microhardness values among tested single shade universal resin composites (p<0.001). Admira Fusion X-tra exhibited the highest mean microhardness value (74.3). A statistically significant decrease in microhardness values was observed after immersion in all beverages (p<0.001). Red wine caused the greatest reduction in microhardness among tested composites. Interactions between composite type, beverage, and time are statistically significant (p=0.001).

Conclusion: Acidic beverages cause significant reductions in the microhardness values of single-shade universal resin composites. Exposure to acidic beverages should be considered when selecting restorative materials.

Keywords: Acidic beverage, microhardness, single-shade universal resin composite, thermal cycling, Vickers.

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INTRODUCTION

Composite resins are widely used in dentistry due to their esthetic appearance and mechanical performance, providing functional restorations with improved longevity. In recent years, single-shade universal resin composites have emerged as innovative materials, offering simplified application techniques and enhanced shade-matching capabilities (Cruz da Silva et al., 2023; Pereira Sanchez et al., 2019). These materials eliminate the need for multiple shade options by relying on their optical blending properties, simplifying the selection process for clinicians.

Single-shade universal resin composites consist of organic matrices, inorganic fillers, and coupling agents. The organic matrix typically includes Bis-GMA, UDMA, and TEGDMA, which provide polymerization flexibility and strength. Inorganic fillers, improve wear resistance and mechanical durability (Turk et al., 2024). Nano-hybrid and nano-filled formulations enhance polishability and surface smoothness, contributing to esthetic outcomes and resistance to staining (Zhang et al., 2021). Their ability to adapt to the surrounding environment makes them suitable for both anterior and posterior restorations, addressing both functional and esthetic needs (Bektas et al., 2024).

Recent studies have evaluated the mechanical behavior and color stability of single-shade composites, emphasizing their optical blending effects and shade adaptation capabilities for esthetic outcomes (Korkut et al., 2023; Villalta et al., 2020; Gencer et al., 2023). Testing protocols, including ISO standards, are essential for assessing composite performance, while non-standardized *in vitro* tests complement these by offering insights into durability under simulated clinical conditions (Heintze & Zimmerli, 2011a,b). These emphasize the importance of assessing composite performance under realistic oral conditions to predict material reliability (Lucena et al., 2023). Microhardness testing, such as the Vickers method, is crucial for assessing the durability and wear resistance of resin composites.

Duratbegovic et al. (2023) highlighted that polymerization parameters, including light intensity, exposure time, and distance, significantly influence Vickers microhardness values and temperature rise during curing. Proper optimization of these variables is essential to achieving uniform polymerization and mechanical stability (Zhu et al., 2023). Hardness values reflect the material's ability to withstand mechanical forces and resist deformation, directly impacting clinical longevity (Sharma et al., 2021). Assessing these values helps to determine material suitability for functional restorations, particularly under varying oral conditions that involve thermal and mechanical stress (Szalewski et al., 2024). Evaluating hardness under simulated conditions, including solution immersion and thermal cycling, provides insight into material performance under stress (Bagheri et al., 2019). Such analyses help to predict how these materials behave in oral environment, guiding clinicians in material selection and improving restorative outcomes (Ren et al., 2023). Moreover, hardness measurements provide indirect information about the degree of conversion and polymerization quality, which are crucial for ensuring optimal physical properties and clinical performance (Yılmaz Atalı et al., 2023).

Single-shade universal resin composites are designed for use in both anterior and posterior regions, offering not only esthetic benefits but also notable mechanical strength (Dietschi & Fahl, 2016). However, their long-term clinical success depends on their resistance to external factors, such as environmental conditions and dietary habits (Beltrami et al., 2018). In the moist oral environment, composites exposed to temperature changes can absorb substances that contribute to restoration failure, leading to discoloration and patient dissatisfaction. Beverages commonly consumed in daily life -such as coffee, red wine, cola, and green tea- may negatively affect both the esthetic and mechanical properties of resin composites (Küden et al., 2023). Addressing this issue often requires restoration replacement, which may result in unnecessary loss of healthy tooth structure (Bozkaya et al., 2018).

The present study investigates the effects of different beverages on the microhardness values of single-shade universal resin composites using the Vickers hardness test. By evaluating mechanical changes, this research aims to provide valuable data for optimizing restorative material selection and application.

The null hypotheses of the study were as follows:

1. There is no difference in microhardness values among different universal resin composites immersed in same beverages.

2. There is no difference in microhardness values of universal resin composites immersed in different beverages.

MATERIALS AND METHODS

Eight single-shade universal resin composite materials from different manufacturers were used in this study: Admira Fusion X-tra (Voco), Charisma Diamond One (Kulzer), Charisma Topaz One (Kulzer), Essentia Universal (GC), Omnichroma (Tokuyama), Optishade (Kerr), Vittra APS Unique (FGM), and Zenchroma (President Dental). The details of these composites, including brand names, manufacturers, monomer compositions, filler types, filler loadings, and lot numbers, are provided in Table 1.

Table 1. The brand names, manufacturers, monomer compositions, filler types, filler loadings, and lot numbers of the single-shade universal resin composites used in the study.

Composite		Manufacturer	Type	Monomer	Filler Composition/Size	Filler by wt/ vol%	Lot Number
Admira Fusion X-tra	AF	VOCO, Germany	Nanohybrid	ORMOCER	Silicon dioxide nanofillers (20-50 nm) and silicon oxide-based hybrid fillers	84/na	2418360
Charisma Diamond One	CD	Kulzer, Germany	Nanohybrid	UDMA TCD-U TEGDMA	B2O3-F-Al2O3-SiO2, silica, TiO2, fluorescent, metallic oxide, organic pigments,5 -20 µm	81/64	K010021
Charisma Topaz One	CT	Kulzer, Germany	Nanohybrid	UDMA, TCD-U TEGDMA	Ba–Al–B–F–Si glass, PPF, SiO2	75/59	K010204
Essentia Universal	GE	GC, Japan	Microhybrid	UDMA Bis-MEPP Bis-EMA Bis-GMA TEGDMA	PPF (17 µm): strontium glass (400 nm), lanthanide fluoride (100 nm), fumed silica (16 nm) FAlSi glass (850 nm)	81/na	2211181
Omnichroma	OC	Tokuyama, Japan	Supra-nanofiller	UDMA TEGDMA	Uniform sized supra-nano spherical filler (260 nm spherical SiO2-ZrO2) and CF	79/68	2652
Optishade	OP	Kerr, USA	Nanohybrid	Bis-EMA Bis-GMA TEGDMA	PPF, BaO-Al2O3-SiO2, silica, and F3Yb, organic fillers Smallest: 5 nm, Largest: 400 nm, average particle size: 50 nm	81/64.5	8242079
Vittra APS Unique	VU	FGM, Brasil	Nanohybrid	UDMA TEGDMA	Zirconia charge, silica (200 nm)	82/72	230921
Zenchroma	ZC	President, Germany	Microhybrid	UDMA Bis-GMA TEMDMA	Glass powder, silicon dioxide inorganic filler (0.005-3.0 µm).	75/53	2022003727

Abbreviations: Bis-GMA = Bisphenol A-glycidyl methacrylate; TEGDMA = triethylene glycol dimethacrylate; UDMA = urethane dimethacrylate; TCD-U: Tricyclodecane-urethane dimethacrylate; PPF = pre-polymerized filler; SiO2 = silicon oxide (silica); ZrO2 = zirconium oxide; BaO-Al2O3-SiO2 = Barium aluminosilicate glass; TiO2 = Titanium dioxide, YbF3 = Ytterbium trifluoride; B2O3-F-Al2O3-SiO2 = Boro-fluoro-aluminosilicate; CF = Composite filler; Bis-EMA = Ethoxylated bisphenol-A Di methacrylate; Bis-MEPP = Bisphenol-A ethoxylate Di methacrylate; TEMDMA = Tetra-ethylen Di methacrylate; fAlSi = fluoroaluminosilicate; na: not available. * The data were provided by the manufacturers.

Power analysis was performed using G*Power 3.1.9.6 software (Heinrich Heine University, Germany) to determine the appropriate sample size. Despite the large effect sizes reported in the literature, a high effect size (f = 0.4) defined by Cohen (1988) was adopted to ensure the reliability of the study and avoid overpowered results. The analysis indicated that a minimum of 7 samples per group was required for 48 groups, with a 95% confidence level ($\alpha = 0.05$) and 95% power ($1-\beta = 0.95$). Considering potential sample loss (drop-out), 9 samples per group were planned. In this context, a total of 432 samples were prepared (n=9) and were divided into a control group stored in distilled water (DW) and experimental groups immersed in coffee (CO), red wine (WN), coke (CC), multivitamin (MV), and green tea (GT). The brand names, manufacturers, pH of the beverages used in this study are presented in Table 2.

Table 2. The brand names, manufacturers and pH of the beverages used in the study.

Beverage	Manufacturer	pH
Distilled Water	N/A	7.0
Coffee	Nestle, Switzerland	5.0
Red Wine	Anycra, Türkiye	3.5
Coke	The Coca Cola Company, USA	2.5
Multivitamin	Redoxon, Germany	3.0
Green Tea	Lipton, UK	6.0

Samples were prepared using metal molds with a diameter of 10 mm and a thickness of 2 mm. Restorative materials were placed in the molds using a Teflon spatula, covered with a transparent polyester strip, and pressed with a glass slide to ensure a smooth surface.

Polymerization was performed using a VALO LED curing unit (Ultradent, USA) at 1000 mW/cm^2, following the manufacturer's instructions, ensuring light exposure on both top and bottom surfaces. To remove the oxygen-inhibited layer, samples were polished using Sof-Lex polishing disks (3M ESPE, USA) in coarse, medium, fine, and superfine grits, as recommended by the manufacturer. Each step lasted 15 seconds and samples were further polished using Eve Diacomp system (Eve Ernst Vetter GmbH, Germany) to achieve a uniform and smooth surface.

All samples were stored in distilled water at 37°C for 24 hours before baseline measurements (t_0). Three random Vickers indentations were performed on each sample using INNOVATEST 412A Vickers Hardness Tester (INNOVATEST Europe, Netherlands). The indentations were made with a 0.49N/g load and a dwell time of 15 seconds. The average of the three measurements was calculated and recorded as the initial microhardness value for each sample.

Samples underwent 5000 thermal cycles between 5-55°C, with a dwell time of 30 seconds in each bath and a transfer time of 10 seconds between baths, simulating 6 months of clinical use as recommended by ISO:11405 standards for thermocycling protocols. This process was designed to replicate the thermal stresses experienced in the oral cavity due to consumption of hot and cold beverages (Morresi et al., 2014).

Following thermal cycling, samples were immersed in prepared solutions at 37°C for a duration of 6 days simulating 6 months of clinical use (Schneider et al., 2024), with daily replacement to ensure consistency and stability throughout the experimental period. Samples were vertically immersed in the beverages to ensure complete and uniform contact with all surfaces. Distilled water (pH 7.0) was stored at room temperature. Multivitamin (pH 4.0) was formulated by dissolving one effervescent tablet in 200 ml of distilled water, also stored at room temperature to mimic clinical conditions. Coke (pH 2.5) and red wine (pH 3.5) were refrigerated at 4°C; green tea (pH 6.0) and coffee (pH 5.0) were freshly prepared using hot water (80°C) prior to use to reflect their typical consumption temperatures.

Following the immersion period, Vickers microhardness testing was conducted again under identical conditions to assess post-immersion changes. Measurements taken after immersion and thermal cycling were recorded as t_1 values, which were compared to the baseline (t_0) to evaluate changes in hardness.

Data were analyzed using Jamovi 2.5.6. Normal distribution was analyzed using the Shapiro-Wilk test. Since the microhardness values were not normally distributed by composite, beverage, and time, robust ANOVA was performed using the Walrus package. Multiple comparisons were analyzed using the Bonferroni test. Quantitative data were presented as trimmed mean±standard error, and statistical significance was set at p<0.05.

RESULTS

Statistical analysis revealed that composite type, beverage type, and immersion time had a significant effect on the microhardness of single-shade universal resin composites (p<0.001). Furthermore, all interactions among these three variables were also found to be statistically significant (p=0.001) (Table 3).

Table 3. Comparison of microhardness values according to composite, beverage, and time.

	Test Statistics	p*
Composite	267514.000	**<0.001**
Beverage	178.000	**<0.001**
Time	134.000	**0.001**
Composite x Beverage	420.000	**0.001**
Composite x Time	521.000	**0.001**
Beverage x Time	205.000	**0.001**
Composite x Beverage x Time	347.000	**0.001**

*Robust ANOVA, p<0.05

Baseline microhardness values (t_0; mean=65.0) were slightly higher than post-immersion values (t_1; mean =64.0). Based on the composites, the initial microhardness values (t_0) from highest to lowest, were as follows: AF: 74.6, ZC: 71.3, CD: 71, CT: 70.2, VU: 64.9, OP: 64.7, OC: 57.5, GE: 40.3. The microhardness values of composites following immersion in solution are listed in descending order as follows: AF: 73.5, CD: 70.8, ZC: 70.3, CT: 64.9, VU: 64.4, OP: 64.3, OC: 58.8, and GE: 40.2 (Table 4).

The main effect of composite type, beverage, and the interaction between composite type and beverage were statistically significant on change in microhardness values (p<0.001) (Table 5).

Table 4. Descriptive statistics and multiple comparisons of microhardness values according to composite, beverage, and time.

Time	Composite	Beverages						Main effect*
		CO	CC	DW	GT	MV	RW	
t0	AF	75 ± 0.136	74.5 ± 0.291	74.7 ± 0.237	74.1 ± 0.455	74.2 ± 0.335	74.6 ± 0.338	74.6 ± 0.125
	CD	71.3 ± 0.344	71.5 ± 0.224	70.4 ± 0.226	70.8 ± 0.327	71.1 ± 0.222	70.6 ± 0.236	71 ± 0.116
	CT	70.1 ± 0.478	70.2 ± 0.398	69.4 ± 0.713	70.5 ± 0.319	70.7 ± 0.508	70.3 ± 0.447	70.2 ± 0.175
	GE	40.3 ± 0.169	40.3 ± 0.169	40.4 ± 0.23	40.1 ± 0.171	40.2 ± 0.22	40.3 ± 0.078	40.3 ± 0.064
	OC	57.1 ± 0.566	58.3 ± 0.617	58 ± 0.633	59 ± 0.564	55.5 ± 1.083	56.9 ± 0.588	57.5 ± 0.295
	OP	65.1 ± 0.227	65.2 ± 0.328	64.8 ± 0.256	64.1 ± 0.441	64.6 ± 0.398	64.5 ± 0.098	64.7 ± 0.128
	VU	64.1 ± 0.413	63.4 ± 1.416	65.2 ± 0.227	65.2 ± 0.208	64.6 ± 0.355	65.2 ± 0.282	64.9 ± 0.15
	ZC	71.1 ± 0.298	71.7 ± 0.221	70.8 ± 0.19	69.8 ± 0.887	71.7 ± 0.152	72.1 ± 0.21	71.3 ± 0.149
	Total	64.9 ± 1.38	65 ± 1.37	64.8 ± 1.34	64.8 ± 1.34	64.7 ± 1.39	64.9 ± 1.38	65 ± 0.554
t1	AF	74.8 ± 0.174	74.9 ± 0.091	74.8 ± 0.135	74.6 ± 0.122	74.8 ± 0.116	64.9 ± 0.962	73.5 ± 0.544
	CD	71.3 ± 0.664	71.1 ± 0.155	70.9 ± 0.408	70.4 ± 0.235	70.6 ± 0.189	70.5 ± 0.228	70.8 ± 0.129
	CT	64.3 ± 0.188	64.8 ± 0.352	68.5 ± 0.763	64.4 ± 0.221	64.3 ± 0.176	63.9 ± 0.114	64.9 ± 0.26
	GE	40.2 ± 0.075	40.1 ± 0.132	40.4 ± 0.129	40.5 ± 0.128	40.1 ± 0.197	40 ± 0.155	40.2 ± 0.059
	OC	58.6 ± 0.309	58.4 ± 0.15	59.5 ± 0.185	59.6 ± 0.227	59.5 ± 0.339	56.9 ± 0.227	58.8 ± 0.168
	OP	65 ± 0.17	65 ± 0.131	64.9 ± 0.156	65 ± 0.176	64.7 ± 0.119	60.2 ± 0.257	64.3 ± 0.269
	VU	65.9 ± 1.316	64.5 ± 0.164	64.3 ± 0.273	63.6 ± 1.235	64 ± 0.507	64.1 ± 0.229	64.4 ± 0.124
	ZC	70.6 ± 0.259	70.5 ± 0.232	70.7 ± 0.294	70.3 ± 0.161	69.9 ± 0.14	70.1 ± 0.245	70.3 ± 0.09
	Main effect**	64.4 ± 1.34	64.2 ± 1.33	64.8 ± 1.32	64.1 ± 1.3	64 ± 1.3	61.9 ± 1.2	64 ± 0.53

*Composite main effect regardless of solution. **Main effect of solution regardless of composite. Trimmed mean±standard error (trimming rate=0.05).

Table 5. Comparison of change in microhardness values (ΔVHN) according to composite and solution.

	Test Statistics	p*
Composite	30.800	**<0.001**
Beverage	12.300	**<0.001**
Composite x Beverage	131.600	**<0.001**

*Robust ANOVA, p<0.05

The mean ΔVHN values of the single-shade universal resin composites, ranked from highest to lowest, were as follows: CT: 5.73; ZC: 1.22; OC: 0.92; VU: 0.68; CD: 0.38; OP: 0.31; AF: 0.06; and GE: 0.06. According to the findings, the CT composite showed the highest mean ΔVHN value (5.73), indicating a significantly greater microhardness change than all other composites. In contrast, AF and GE exhibited the lowest values (0.06), with AF forming a distinct statistical group, suggesting superior resistance to surface hardness alteration. The other materials (ZC, OC, VU, OP, CD) demonstrated intermediate values with overlapping statistical groups, implying no significant differences among some of them (Table 6).

The average ΔVHN values based on beverage type, ranked from highest to lowest, were as follows: RW: 1.7; MV: 0.5; CC: 0.48; DW: 0.19; GT: 0.15; and CO: 0.09. RW exhibited a statistically significantly higher microhardness change value compared to all other beverages, whereas no significant difference was observed among CO, CC, GT, and MV. When the interaction of resin composites with beverages was examined, AF showed the highest average ΔVHN (Table 6)(Figure 1).

DISCUSSION

The results of this study demonstrated that single-shade universal resin composites exhibit different levels of microhardness. This variability among the composites underscores the role of filler composition, resin matrix properties, and polymerization techniques. The composite formulation plays a significant role in hardness retention and structural stability, emphasizing the importance of material composition in clinical performance.

Table 6. Descriptive statistics and multiple comprasions of microhardness change (ΔVHN) values according to composite and beverage.

Composite	Beverage						
	CO	CC	DW	GT	MV	RW	Main effect*
AF	0.09(-1.01-1)	-0.38(-1.78-0.8)	-0.24(-1.27-0.9)	-0.61(-2.3-0.92)	-0.74(-1.48-0.59)	9.15(5.55-13.47)	0.06(-2.3-13.47)[a]
CD	0.08(-2.44-3.37)	0.54(-0.7-1.69)	-0.49(-2.63-1.38)	0.56(-1.08-1.54)	0.59(-1.29-1.4)	0.12(-0.77-1.18)	0.38(-2.63-3.37)[bc]
CT	5.52(3.38-8)	5.35(3.49-6.31)	0.49(-1.98-3.56)	6.13(4.63-7.29)	7.01(3.85-8.34)	6.5(4.79-8.19)	5.73(-1.98-8.34)[d]
GE	0.07(-0.87-0.81)	0.11(-0.47-1.2)	0.18(-1.82-1.06)	-0.23(-1.19-0.68)	-0.02(-0.61-1.63)	0.37(-0.34-1.06)	0.06(-1.82-1.63)[b]
OC	-1.7(-3.89-0.51)	-0.24(-2.26-3.95)	-1.25(-4.01-1.08)	-0.85(-3-2.54)	-3.38(-8.79-1.06)	0.43(-3.53-2.93)	-0.92(-8.79-3.95)[e]
OP	0.06(-0.7-1.35)	0.58(-1.69-0.9)	0.31(-1.37-1.07)	-0.6(-3.4-1)	-0.43(-2.04-1.89)	4.39(3.01-5.48)	0.31(-3.4-5.48)[cf]
VU	-0.41(-13.07-1.22)	0.37(-10.22-1.91)	0.97(-1.28-2.69)	0.81(-0.37-9.34)	0.65(-1.25-3.74)	0.88(0.21-2.66)	0.68(-13.07-9.34)[cf]
ZC	0.26(-0.72-2.44)	1.55(-0.46-2.1)	-0.02(-2.44-1.47)	-0.4(-5.83-2.46)	1.73(1.18-2.52)	1.78(1.1-3.43)	1.22(-5.83-3.43)[f]
Main effect**	0.09(-13.07-8)[A]	0.48(-10.22-6.31)[A]	0.19(-4.01-3.56)[B]	0.15(-5.83-9.34)[A]	0.5(-8.79-8.34)[A]	1.7(-3.53-13.47)[C]	0.43(-13.07-13.47)

*Main effect of composite regardless of solution. **Main effect of solution regardless of composite. Median (minimum-maximum); A-C: No significant difference between solutions sharing the same capital letter in the same row. a-f: No significant difference between composites sharing the same lowercase letter in the same comparisons.

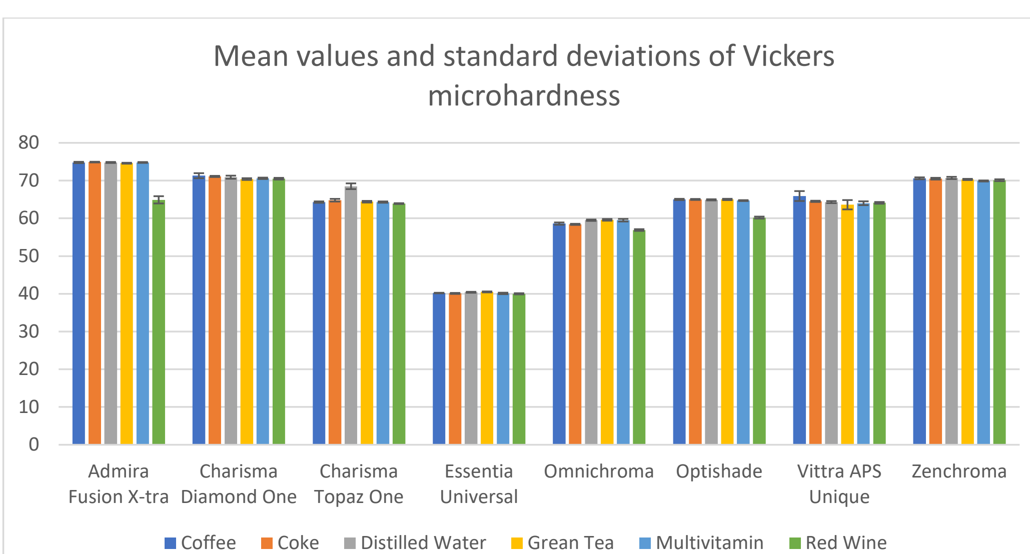

Figure 1. Mean and standard deviation of Vickers microhardness of resin composites after immersion in different beverages (t_1).

Studies reported nano-hybrid formulations, such as Charisma Topaz, exhibited higher hardness values due to improved filler structure, while composites with larger pre-polymerized particles, like Essentia Universal, demonstrated lower hardness values (Sarıalioğlu Güngör et al., 2023). Similarly, in our study, Charisma Topaz showed a mean microhardness value of 70.2, significantly higher than Essentia Universal, which exhibited a mean value of 40.3. These results suggest that composites with higher filler loads may demonstrate better resistance to degradation (Abreu et al., 2023).

In this study, Charisma Diamond, with a superior mean value of 71, displays the advantages of its nanohybrid filler structure, which significantly enhances mechanical strength and resilience. Omnichroma had a mean microhardness value of 57.5, which reflects moderate performance due to its spherical filler composition that balances esthetics and durability. Vittra APS Unique also performed favorably, with a mean value of 64.9, supported by advanced polymerization technology, contributing to its structural stability. These findings are consistent with those of Alharbi et al. (2024), who highlighted the critical roles of filler type and polymerization efficiency in determining the clinical performance and longevity of composite materials.

These findings led to the rejection of the first null hypothesis, which stated that there would be no statistically significant difference in microhardness values of different single-shade universal resin composites immersed in the same beverage. Similarly, the second null hypothesis was also rejected, indicating a statistically significant difference in microhardness values of universal resin composites when immersed in different beverages.

Acidic beverages, including coke, multivitamin, and particularly red wine, significantly reduced the microhardness values of composite resins, consistent with recent findings (AlSheikh et al., 2023; Vejendla et al., 2024). These beverages exert erosive effects by softening the resin matrix (Karatas et al., 2023) and weakening the filler-resin interface, leading to increased hardness degradation, roughness, and solubility (Kedici Alp et al., 2023; Hamouda, 2023).

The comparatively lower reductions in hardness values observed in samples stored in distilled water and green tea indicate that neutral and slightly alkaline environments provide better protection against structural degradation. This supports the notion that pH-neutral conditions are less aggressive toward resin composites, preserving their physical properties (Poggio et al., 2021).

The interaction effects between composite and beverage underscore the importance of evaluating materials not only in isolated conditions but also in simulated clinical environments involving multiple stressors. The highest interaction value was observed with Admira Fusion X-tra composite immersed in coffee, reaching 74.9, reflecting its superior resistance under these conditions. Conversely, the lowest interaction value of 40.1 was recorded for Essentia Universal composite immersed in multivitamin, highlighting vulnerability to environmental stressors. These observations highlight the importance of evaluating the performance of resin composites under acidic and thermally stressed conditions to ensure long-term clinical reliability.

The thermal cycling used in this study effectively mimicked intraoral temperature fluctuations, demonstrating its relevance for predicting long-term performance. Expansion and contraction induced by thermal stress can increase micro-cracks, emphasizing the need for combined thermal and chemical testing (Tüter Bayraktar et al., 2023). Accelerated aging processes and thermal cycling significantly affect microhardness and surface stability, emphasizing the relevance of Vickers hardness testing in evaluating structural changes (Fidan, 2023; Abouelmagd & Basheer, 2023).

Polymerization parameters, such as light intensity and exposure duration, influence conversion, hardness, and stability. In this study, polymerization was performed using a VALO LED curing unit (Ultradent, USA) at 1000 mW/cm^2 in standard power mode, ensuring uniform curing on both the top and bottom surfaces, as recommended by the manufacturer. This approach minimized the risk of incomplete polymerization, enhancing mechanical durability and performance (Korkut et al., 2023).

It is well known that, proper finishing and polishing enhance surface quality, reduce bacterial adhesion, and support long-term performance (Atalay et al., 2023; Bernaldo-Faustino et al., 2023; Chowdhury et al., 2023). In this study, finishing was performed using Sof-Lex disks in sequential grits, followed by the Eve Diacomp polishing system, as recommended by the manufacturer. This multi-step approach ensured a smooth and uniform surface, which is essential for minimizing surface irregularities that could compromise mechanical properties and durability.

This study underscores the importance of durability assessment for single-shade universal resin composites, as all materials tested exhibited microhardness values in accordance with ISO standards, confirming their clinical viability. Additionally, the observed decrease in microhardness values post-immersion highlights the need for regular maintenance and polishing to prolong the esthetic and functional lifespan of composites.

However, this study has several limitations. Since it was conducted *in vitro*, it could not fully replicate the dynamic oral environment, including saliva flow, pH fluctuations, biofilm formation, and mechanical forces. The immersion protocol involved continuous exposure, which does not reflect the intermittent consumption of beverages in real life. Additionally, maintaining beverages at 37°C does not simulate varying drinking temperatures. Although 5000 thermal cycles were applied to simulate 6 months of clinical use, this may be insufficient to assess long-term stability. The absence of simulated chewing forces and wear also limits the evaluation of microhardness and surface properties.

CONCLUSION

Within the limitations of this *in vitro* study, it can be concluded that environmental factors, including immersion in beverages and thermal cycling, significantly affect the micro hardness of single-shade universal resin composites. Key findings are summarized as follows:

1. Acidic solutions, particularly coke and red wine, caused the greatest reductions in microhardness values, potentially compromising structural integrity.
2. Neutral and slightly alkaline solutions, such as distilled water and green tea, preserved microhardness values more effectively, offering better resistance to degradation.
3. Composite formulation plays a crucial role in hardness retention, with nano-filled and advanced polymer matrix composites showing superior performance.
4. All tested composites met ISO:4049 standards for microhardness, confirming their clinical suitability despite variations in performance.
5. Thermal cycling and chemical exposure influenced material behavior, underscoring the need for durability testing under simulated oral conditions.

These results emphasize the importance of selecting restorative materials based on their resistance to environmental factors. Future studies should explore long-term effects involving mechanical fatigue, dynamic loading, and advanced surface treatments to enhance material performance and clinical reliability.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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