Clinical and Experimental Health Sciences

Effect of Polishing Systems on the Color and Surface Properties of Resin Composites in the Process of Accelerated Artificial Aging

Muhammet Fidan[1], Zeynep Dereli[2]

[1] Usak University, Faculty of Dentistry, Department of Restorative Dentistry, Usak, Türkiye.

[2] Necmettin Erbakan University, Faculty of Dentistry, Department of Restorative Dentistry, Konya, Türkiye.

Correspondence Author: Muhammet Fidan
E-mail: muhammetfidan93@gmail.com
Received: 24.10.2021 **Accepted:** 22.03.2022

ABSTRACT

Objective: This study aimed to investigate the effects of polishing system on the color stability, surface roughness, and hardness of resin composites in the presence and absence of accelerated artificial aging (AAA).

Methods: Six resin composites (Universal Restorative 200, G-Aenial Anterior, Ceram-X Duo, Admira, IPS Empress Direct, Clearfil Majesty Esthetic) were evaluated. Thirty disc-shaped samples were prepared for each composite group. Resin composite groups were divided into three subgroups: control (Mylar strip), disc (Optidisc), and rubber (Dimanto) (n=10). Color change (ΔE_{00}) was calculated using the CIEDE 2000 formula. Before and after AAA, the surface roughness (Ra, µm) and hardness (VHN) values were measured. Data were analysed using ANOVA, the Bonferroni test, and Pearson correlation ($p<0.05$).

Results: The Mylar strip group showed less color change than the polished groups. Universal Restorative 200 and IPS Empress Direct were associated with less discoloration than other resin composite groups. Before AAA, Mylar strips and Universal Restorative 200 were exhibited smoother values. There was no difference in the surface roughness between Dimanto-treated resin composites those associated with other materials before and after AAA (except Ceram-X Duo and Universal Restorative 200). Universal Restorative 200 yielded higher hardness values than other composites ($p<0.05$). The Mylar strips yielded lower VHN values than the polished groups, but there were no differences among the polishing systems. There was a significant, weak, and positive correlation between color and roughness change.

Conclusion: Composite type, finishing/polishing, and AAA had statistically significant effect on surface roughness and hardness. The Optidisc group exhibited less coloration and smoother surfaces than the Dimanto group. Nanohybrid (IPS Empress Direct) and microhybrid (Universal Restorative 200) resin composites performed better than other resins in terms of color change and roughness. Polishing systems applied to resin composite materials increased hardness.

Keywords: Accelerated artificial aging, color change, polishing, surface properties

1. INTRODUCTION

With developments and improvements of the physical-mechanical properties of resin composites, their clinical use has increased; however, color stability, which affects the life of the restoration, remains a material-specific problem (1). Color change in resin composites is multifactorial, depending on the internal and external coloring of the materials. Internal factors are related to the chemical structure of the resin matrix component of the materials, and external factors are related to the coloring substances (such as the patient's diet, hygiene, smoking habits) (2). Color differences can be assessed visually or with color-measuring instruments. These instruments (colorimeters and spectrophotometers) quantitatively indicate coloration and avoid the pitfalls of subjective visual color comparisons (3). The CIEDE 2000 formula provides better correlations than the CIE L*a*b formula, and the CIEDE 2000 formula determines color differences perceived by the human eye better than the CIE L*a*b formula (4).

The mechanical properties of resin composites in aesthetic restorations are also important factors influencing their clinical longevity (5). Mechanical and physical properties are reflected by differences in filler volume, size, and shape, and improvements in these materials have been implemented via changes in matrix composition and polymerization technology (6). Finishing/polishing can be considered essential steps in restorative procedures that increase the aesthetics and clinical lifespan of restored teeth. Resin matrix and filler particles change in terms of hardness; as a result, they do not wear out to the same plane. Therefore, due to

ISSN:2459-1459

DOI: 10.33808/clinexphealthsci.1012098

the removal of some particles during the process of finishing/polishing, surface defects may occur, such as microcracks and irregularities in the materials, which reduces the wear resistance of the restorations (7). Clinicians can choose from a variety of polishing tools for clinical use, such as diamond burs, stones, rubber cups, bits, discs, strips, and pastes. Efforts have been made to develop finishing/polishing instruments and one-step systems for resin composites (8). Given that simplified application systems are less time-consuming, it is important for clinicians to know which finishing/polishing systems offer adequate surface quality to increase the longevity of resin composite restorations (9).

A clinically useful lifespan begins immediately after the application of restoration materials. Although it may be possible to immediately assess color and other variables related to aesthetics, it is difficult to predict and compare long-term outcomes due to the rapid development and introduction of new generations in the dental market (2). Artificial aging methods are used to evaluate the effects on the optical and mechanical properties of resin composites (10). Clinical studies must validate the treatment procedures, but such studies are expensive and time-consuming. In vitro studies are designed to simulate clinical conditions as closely as possible within the scope of clinical procedures (11). Accelerated artificial aging (AAA) imitates oral conditions through exposure to 300 h of weathering in a weather-O-meter, which is reportedly equivalent to 1 year of clinical use or intraoral treatments (12). AAA imitates the effects of prolonged exposure to environmental factors, such as differences in light, temperature, and moisture, and it approximates long-term clinical use in short time intervals (13). Studies evaluating AAA and resin composite polishing systems are scarce in the literature.

This study aimed to assess the influence of two polishing methods on color changes, surface roughness, and hardness among six resin composites in the presence and absence of AAA. The following null hypotheses were investigated: (1) different polishing methods would not effect color changes, surface roughness and hardness of resin composites; and (2) AAA would not influence color changes, surface roughness and hardness among resin composites.

2. METHODS

Shade equivalent A2 of six different resin composites (Clearfill Majesty Esthetic, Kuraray, Okayama, Japan; IPS Empress Direct, Ivoclar Vivadent, Schaan, Liechtenstein; Universal Restorative 200, 3M-ESPE, St. Paul, MN, USA; G-Aenial Anterior, GC Corp. Tokyo, Japan; Ceram-X Duo, Dentsply, Konstanz, Germany; Admira, Voco, Cuxhaven, Germany) were used (Table 1). Thirty disc-shaped samples were prepared for each composite, adding up to 180 samples in total. A Teflon mould (8 mm diameter and 2 mm thickness) was used to prepare disc-shaped specimens of the resin composites. The resin composites were placed into holes, and a Mylar strip was placed over the top surfaces. Resin composites were cured with light-emitting diode (LED; Woodpecker LED.E (P), Guilin Woodpeckers Medical Inst. Co., Guilin, China)–curing light at 1200 mW/cm^2 for 40 s directly over Mylar strips. The resin composite groups were randomly divided into three subgroups (n=10). Except for the Mylar strip group, 1200 grit silicon carbide abrasive paper was used with water before application using the polishing systems. Two different polishing systems (Optidisc, KerrHawe, Bioggio, Switzerland; Dimanto, Voco, Cuxhaven, Germany) were used. The polishing systems are shown in Table 1. The four-step OptiDisc system includes four aluminium oxide (Al_2O_3)–embedded discs, and each was used for 15 s in dry conditions. The one-step Dimanto system (rubber cup) includes diamond-embedded discs and was used for 60 s in dry conditions. The polishing systems were applied using a handpiece at a speed of 10,000 rpm. All the specimens were rinsed for 10 s and then stored at 37°C for 24 h in distilled water.

2.1. Color Change Measurements

The initial color measurements were performed using a spectrophotometer (Lovibond RT Series, Tintometer Group, Lovibond House, UK). The spectrophotometer was calibrated according to the manufacturer's instructions. The CIEDE 2000 formula was used to determine color differences (14,15):

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L} \right)^2 + \left(\frac{\Delta C'}{K_C S_C} \right)^2 + \left(\frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C} \right) \left(\frac{\Delta H'}{K_H S_H} \right) \right]^{\frac{1}{2}}$$

where ΔL⍰, ΔC⍰, and ΔH⍰ are the differences in lightness, chroma, and hue, respectively, between two specimens. The relationship between the variations of chroma and hue in the blue region is defined by the rotation function (R_T). The weighting functions of lightness, chroma, and hue are denoted by S_L, S_C, and S_H, respectively. K_L, K_C, and K_H are the parametric factors of set 1 in this study (16).

2.2. Surface Roughness Measurements

Initial surface roughness was measured using a contact surface roughness device (Mar Surf PS1, Mahr, Göttingen, Germany). The average roughness (Ra, µm) values were recorded, and each specimen was recorded three different times using a profilometer, and the average value was calculated for each.

2.3. Surface Hardness Measurements

Initial surface hardness was measured using a surface hardness device (LHV-1D, Bursam NDT, Bursa, Turkey). A 300-g load with a 10-second dwell period (17) was used on the surface for three measurements, and the average value was calculated for each material.

Table 1. *List of materials used in present study*

Resin Composites	Manufacturer	Type	Composition	wt-vol	Lot No.
Universal Restorative 200	3M Espe, St. Paul, MN, USA	Universal/ Microhybrid	BisGMA, UDMA, Bis-EMA, zirkonium/silica, 0,01-3,5 µm	%82 wt %60 vol	N996478
G Aenial Anterior	GC Corp. Tokyo, Japan	Microhybrid	UDMA, dimethacrylate co-monomers, pre – polymerized organic filler, silica, strontium, lanthanoid fluoride, fumed silica (0,1–17µm)	%73 wt %64 vol	1909091
Ceram.X Duo (Enamel)	Dentsply De Trey GmbH, Konstanz, Germany	Nanoceramic	Bis-GMA, UDMA, TEGDMA, Methacrylate modified ploysiloxane (organically modified ceramic), dimethacylate resin, Bis(4-methyl-phenyl), iodonium hexafluorophosphate, barium-aluminum-borosilicate glass (10 nm), methacrylate functionalised silicon dioxide nano filler	%76 wt %57 vol	180.800.1099
Admira	Voco GmbH Cuxhaven, Germany	Ormocer	Ormocer, BisGMA, UDMA, aromatic and aliphatic dimethacylate, 0.7 µm.	%78 wt. (%56 vol. microfiller)	1914502
IPS Empress Direct (Enamel)	IvoclarVivadent, Schaan, Liechtenstein	Nanohybrid	BisGMA, UDMA, TEGDMA, Barium glass, ytterbium trifluoride, and mixed oxides silicon dioxide, copolymer 0,4 µm-100 nm	%75-79 wt %52-59 vol	Y35243
Clearfil Majesty Esthetic	Kuraray Noritake Dental Inc., Okayama, Japan	Nanohybrid	BisGMA, hydrophobic aromatic dimethacrylate, di-Camhorquinone, silanated barium glass filler, pre – polymerized organic filler, 0,37 µm-1,5 µm	%78 wt %40 vol	4H0173
Finishing/ Polishing materials	**Manufacturer**	**Type**	**Composition**		**Lot No.**
OptiDisc	KerrHawe, Bioggio, Switzerland	Discs	Aluminum impregnated discs, (Coarse-Medium-Fine-Extrafine)		6778506
Dimanto	Voco GmbH Cuxhaven, Germany	Rubber	Diaomond particles impregnated silicon rubber (One-step pre and high gloss polishing)		1915625

Bis-GMA; bisphenol A glycol dimethacrylate; Bis-EMA; bisphenol A ethoxylated dimethacrylate; TEGDMA; triethylene glycol dimethacrylate, UDMA; urethane dimethacrylate.

2.4. AAA

After initial measurements, all specimens were aged for 300 h and 150 kJ/m^2 (3) in an accelerated ageing chamber (Atlas ci 4000; Atlas Electronic Devices Co, Mount Prospect, Il, USA) (18). The aging procedure was performed as described elsewhere (19). After AAA procedures, color change, surface roughness and hardness measurements were repeated.

2.5. Statistical Analysis

Statistical analysis was performed using SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). First, the normality of the distribution was checked. Paired-samples t-test analysis was used to make before-and-after comparisons to examine the significance of the effects of AAA on the roughness and hardness of the resin composite materials. Independent-samples t-tests were used to compare color changes, surface roughness, and surface hardness of the polishing systems used for the resin composite materials. Color change was analysed using two-way ANOVA. Three-way ANOVA was used to analyse the interaction between composite type, polishing systems, and AAA in the influence of surface roughness and hardness of the composites. Bonferroni tests were used for multiple comparisons. Pearson correlation was used to reveal the relationship between changes in color and surface roughness values. For all statistical tests, the significance level was set at $p<0.05$.

3. RESULTS

3.1. Color Results

Table 2 shows ΔE_{00} values. The analysed factors (composite type and finishing/polishing group) had no significant influence on color changes (Table 3). The ΔE_{00} values of the Ceram-X Duo were indicated to be statistically significantly higher than those of the Universal Restorative 200 and IPS Empress Direct ($p<0.001$). The Optidisc and Dimanto groups were found to have significantly higher mean ΔE_{00} values than the Mylar strip group ($p<0.001$ for each). The Dimanto group had a significantly higher mean ΔE_{00} value than the Optidisc group ($p=0.017$).

Table 2. ANOVA results for color change (ΔE_{00})

Interaction factors	Type III Sum of Squares	df	Mean Square	F	p
Group	30.5	2	15.226	24.14	**<0.001**
Composite type	61.6	5	12.321	19.530	**<0.001**
Group * Composite type	10.5	10	1.051	1.670	0.093

Table 3. Mean color changes (ΔE_{00}) and standard deviation of the tested materials

Resin composites	Control	Optidisc	Dimanto	Total
Ceram-X Duo	3.54 ± 0.83	4.21 ± 0.54	4.39 ± 0.47	4.39 ± 0.47 A
Universal Restorative 200	2 ± 0.56	2.9 ± 0.89	3.3 ± 1.13	2.73 ± 1.02 B
G-Aenial Anterior	3.68 ± 0.93	4.28 ± 1.11	4.34 ± 0.61	4.1 ± 0.93 A
IPS Empress Direct	2.52 ± 1.24	2.57 ± 0.57	2.86 ± 0.57	2.65 ± 0.84 B
Clearfil Majesty Esthetic	2.9 ± 0.44	4.16 ± 0.36	4.33 ± 0.75	3.8 ± 0.84 A
Admira	3.01 ± 0.49	3.12 ± 1.29	4.43 ± 0.56	3.52 ± 1.06 A
Total	2.94 ± 0.96 a	3.54 ± 1.08 b	3.94 ± 0.93 c	

Different capital letters represent statistically significant differences in each column (p< 0.05).
Different lower letters represent statistically significant differences in each row (p< 0.05).

3.2. Surface Roughness Results

The analysed factors (composite type, finishing/polishing group, and AAA) had a statistically significant influence on surface roughness (Table 4), and Ra value differences are shown in Table 5. Before AAA, when the compared resin composites in the rubber group were evaluated according to composite type, there were no significant differences (p>0.05). The Ceram-X Duo yielded higher Ra values than the Universal Restorative 200 (p=0.046). The Optidisc with Universal Restorative 200 yielded significantly lower Ra values than the other composites. However, there were no differences between the Ra values associated with IPS Empress Direct and Clearfil Majesty Esthetic. After AAA, Optidisc and Dimanto with Universal Restorative 200 were associated with significantly lower surface roughness values than Ceram-X Duo (p=0.014, p=0.035, respectively). Before and after AAA, the Mylar strip group exhibited lower Ra values than the finishing/polishing groups (p<0.001). Additionally, the Optidisc group exhibited significantly lower roughness values than the Dimanto group (p<0.001).

3.3. Surface Hardness Results

The analysed factors (composite type, finishing/polishing group, and AAA) had a statistically significant influence on surface hardness (Table 4). Vickers hardness number (VHN) differences are shown in Table 6. Among all finishing/polishing groups, the Universal Restorative 200 exhibited the highest VHNs (p<0.05). The polishing groups exhibited significantly higher hardness values than the control group. Before and after AAA, no significant difference was observed between the Optidisc and Dimanto groups in terms of hardness.

Table 4. Interactions among the three factors using Three-Way ANOVA

Interaction factors	Roughness	Hardness
	p	p
Composite	**<0.001**	**<0.001**
Group	**<0.001**	**<0.001**
AAA	**<0.001**	**<0.001**
Composite* Group	**<0.001**	**<0.001**
AAA*Composite	0.092	0.239
AAA*Group	**0.001**	**<0.001**
AAA* Composite *Group	**0.020**	**<0.001**

3.4. Pearson Correlation Results

There was a statistically significant, weakly positive relationship between color change and roughness (r=0.168, p=0.024).

Table 5. *Surface roughness values (Ra, µm) (mean±std.deviation) of the resin composites*

	Control			Optidisc			Dimanto		
	Before AAA	After AAA	p	Before AAA	After AAA	p	Before AAA	After AAA	p
C	0.19 ± 0.02 Aa	0.21 ± 0.03 ABC^{1}	>0.05	0.25 ± 0.02 ACb	0.28 ± 0.02 A2	<0.05	0.26 ± 0.02 Ab	0.31 ± 0.01 B^{2}	<0.05
U	0.15 ± 0.01 Ba	0.16 ± 0.03 B^{1}	>0.05	0.15 ± 0.02 Ba	0.23 ± 0.03 C^{2}	<0.05	0.24 ± 0.03 Ab	0.27 ± 0.02 A^{2}	<0.05
G	0.17 ± 0.02 ABa	0.22 ± 0.04 C^{1}	<0.05	0.23 ± 0.03 ACb	0.28 ± 0.02 A^{2}	<0.05	0.25 ± 0.03 Ab	0.31 ± 0.03 AB^{2}	<0.05
I	0.16 ± 0.04 ABa	0.18 ± 0.02 ABC^{1}	>0.05	0.18 ± 0.03 BCa	0.21 ± 0.01 BC^{1}	<0.05	0.25 ± 0.02 Ab	0.28 ± 0.01 AB^{2}	<0.05
M	0.17 ± 0.03 ABa	0.18 ± 0.02 AB^{1}	<0.05	0.19 ± 0.01 BCa	0.25 ± 0.02 AC^{2}	<0.05	0.25 ± 0.02 Ab	0.30 ± 0.02 AB^{3}	<0.05
A	0.17 ± 0.02 ABa	0.20 ± 0.03 ABC^{1}	<0.05	0.21 ± 0.04 Ca	0.27 ± 0.03 AC^{2}	<0.05	0.27 ± 0.03 Ab	0.31 ± 0.01 AB^{2}	<0.05

C; Ceram-X Duo, U;Universal Restoratif 200, G;G-Aenial Anterior, I;IPS Empress Direct, M;Clearfil Majesty Esthetic, A;Admira, AAA; Accelerated artificial aging, p; represent statistically significant differences in each group of the same resin composites (between before and after AAA of specimens values)
Different capital letters represent statistically significant differences in each column (p<0.05).
Different lower letters (comparisons of before AAA, specimen values between the groups) represent statistically significant differences in each row (p<0.05).
Different superscript numbers (comparisons of after AAA, specimen values between the groups) represent statistically significant differences in each row (p<0.05).

Table 6. *Surface hardness values (VHN) (mean±std.deviation) of the resin composites*

	Control			Optidisc			Dimanto		
	Before AAA	After AAA	p	Before AAA	After AAA	p	Before AAA	After AAA	p
C	52.00 ±1.75 Aa	67.87 ± 1.93 A^{1}	<0.05	63.51 ± 2.43 Ab	75.74 ± 1.73 AD^{2}	<0.05	60.26 ± 1.72 AEb	73.84 ± 1.51 A^{2}	<0.05
U	87.73 ± 2.20 Ba	92.43 ± 2.04 B^{1}	<0.05	92.09 ± 2.49 Bb	103.48±3.48 B^{2}	<0.05	91.09 ± 2.42 Bab	101.78±4.00 B^{2}	<0.05
G	37.70 ± 1.91 Ca	55.32 ± 2.20 C^{1}	<0.05	43.28 ± 1.68 Cb	60.97 ± 1.64 C^{2}	<0.05	42.83 ± 2.05 Cb	59.60 ± 1.92 C^{2}	<0.05
I	50.50 ± 1.61 Aa	75.76 ± 1.84 D^{1}	<0.05	61.32 ± 1.01 Ab	78.41 ± 1.97 D^{1}	<0.05	58.10 ± 1.36 Ab	77.68 ± 1.99 D^{1}	<0.05
M	43.18 ± 3.53 Da	52.40 ± 1.55 CE^{1}	<0.05	45.65 ± 1.55 Ca	55.34 ± 0.84 E^{1}	<0.05	44.79 ± 1.21 Da	52.55 ± 0.90 E^{1}	<0.05
A	57.91 ± 2.15 Ea	68.03 ± 1.24 A^{1}	<0.05	63.54 ± 1.90 Ab	73.55 ± 2.06 A^{2}	<0.05	61.89 ± 2.05 Eb	71.77 ± 1.50 A^{2}	<0.05

C; Ceram-X Duo, U;Universal Restoratif 200, G;G-Aenial Anterior, I;IPS Empress Direct, M;Clearfil Majesty Esthetic, A;Admira, AAA; Accelerated artificial aging, p; represent statistically significant differences in each group of the same resin composites (between before and after AAA of specimens values)
Different capital letters represent statistically significant differences in each column (p<0.05).
Different lower letters (comparisons of before AAA, specimen values between the groups) represent statistically significant differences in each row (p<0.05).
Different superscript numbers (comparisons of after AAA, specimen values between the groups) represent statistically significant differences in each row (p<0.05).

4. DISCUSSION

The interaction between composite type and polishing system was not significant in terms of the influence on color change. However, significant differences were found in the interaction between the composite resin materials and the polishing systems in terms of surface roughness and hardness. Therefore, we failed to fully reject the first null hypothesis. AAA was associated with significant differences in the color, surface roughness, and hardness of the resin composites. Therefore, the second null hypothesis was rejected.

In this study, acceptable perceptibility and acceptability thresholds were 0.81 and 1.77, respectively (15). Color change ΔE_{00} values were all between 2.0–4.43, and the resin composites were associated with clinically unacceptable color changes after AAA. Resin composite color changes are affected by external and internal factors. External factors include the duration and intensity of light emission during light-curing, as well as environmental factors, such as ultraviolet radiation, water, and temperature. Internal factors include the content of the resin matrix, filler loading and particle size distribution, type of photoinitiators, and remaining C=C bonds (20). During light-curing, initiators and tertiary aromatic amines form products that, under temperature or UV light challenges, cause resin discoloration towards red or yellow (21). A previous study (12) found that L* values decreased and b* values increased in resin composites after AAA. In the present study, L* values decreased and b* values increased in resin composites after AAA. Admira and Ceram-X Duo contain ormocer matrix, which is defined by an interpenetrating network of inorganic-organic polymers (22). In our study, Admira, Ceram-X Duo, G-Aenial Anterior resin composites were associated with more discoloration than the other materials. The staining susceptibility of resin composites may be due to the degree of water sorption and the hydrophilicity of the resin matrix. Resin composites can absorb water and are also able to absorb other fluids with pigments, which results in discoloration (23). Discoloration may be caused by inseparable highly cross-linkable organic networks and inorganic structures (20) and by AAA disrupting the ormocer structure. G-Aenial Anterior consists of a mixture of urethane dimethacrylate (UDMA) and dimethacrylate co-monomers; it is free of Bis-GMA and has been confirmed in previous studies to facilitate discoloration. Bis-GMA and TEGDMA have high water absorption capacity due to their hydrophilic structure. The color stability of UDMA has been demonstrated to be superior to that of Bis-GMA (24); however, our findings were contrary to this observation. G-Aenial Anterior, a microhybrid composite with higher filler volume (64%), did not seem to have advanced color stability compared with Ceram X-Duo and Admira, ormocer-containing materials with lower filler volumes (57% and 56%, respectively). This may indicate that the lower color stability and higher solubility may be associated with monomer structures, for which AAA affects the chemical structures. In a previous study, microhybrid composites were found to be more stain-resistant than nanocomposites and microfilled composites (25). However, in our study, IPS Empress Direct (nanohybrid) exhibited the lowest ΔE_{00} values among the resin composite materials investigated (except for Universal Restorative 200). IPS Empress Direct can resist ageing-related staining. This can be explained by the use of different photoinitiators that remove amine groups, improve polymerization kinetics, and reduce the yellowing effect of curing. Smaller particle size and better dispersion of the resin matrix produces smoother surfaces (24). Although a previous study found that small nanofilled composite resin particles resulted in less discoloration (25), another study found that increased particle size caused a decrease in the organic filler matrix ratio, resulting in less discoloration (26); our study findings with Universal Restorative 200, a microhybrid resin composite, aligned with the latter observation. Use of the Universal Restorative 200 microhybrid and larger particle sizes may be effective for minimizing discoloration.

A previous study investigated color changes, surface morphology, and tooth restoration interface degradation among different resin composites (hybrid, microhybrid, nanoparticle-containing, and silorane) after AAA and found that Filtek Z250 (a microhybrid) was associated with the least color change. It has been stated that physical surface modifications caused by AAA may affect color changes (27) and that color changes caused by AAA are probably due to degradation at the monomer matrix/particle interface (28). An ideal polishing instrument should have abrasive particles harder than the filler contents of the material, thus allowing composites to reduce in terms of both the resin matrix and filler particles during polishing. Soft abrasive particles from the fillers only remove the resin matrix, and the hard aluminium oxide found in most polishing systems is significantly higher harder than most of the fillers in resin composites (29). Lu et al. (30) found that the smoothest surfaces were created using aluminium oxide–coated discs, that can perform an equal amount of abrasion, from both organic resin and inorganic fillers. A previous study evaluated the effects of the aging procedure on the surface roughness of compomer and resin composites (nanohybrid and ormocer). The study found that AAA did not affect the surface roughness, but there were differences between the materials (31). Similarly, another study stated that AAA did not influence the surface roughness of resin composites (32). Increases in color change and surface roughness have been shown to be interrelated (33). Another study (34) reported a lack of statistically significant increases in surface roughness values among resin composites after AAA; the investigators found that there was no correlation between surface roughness and color change. However, in our study, resin composites showed significant increases in surface roughness values after AAA, and a weakly positive correlation was found between roughness change and color change. Surface roughness can influence color change, as surface morphology influences susceptibility to discoloration. Surface roughness evaluation is relevant to the study of composite restoration since surface morphology affects susceptibility to discoloration (23). AAA and polishing produced rougher surfaces, which in turn caused significant color alterations. It has been observed that changes in resin composites are associated with internal factors (34) and external alterations that occur within specimens. A systematic review reported that the surface roughness of nanofiller or submicron composites was not superior to that of conventional microhybrid resin composites (35). In our study, the surface roughness values before and after AAA were found to be between 0.15 and 0.31 µm. Significant differences were observed between the Ceram-X Duo and Universal Restorative 200 control groups before AAA. After AAA, differences were detected between the two microhybrid resin composites (Universal Restorative 200 and G-Aenial Anterior). These differences can be attributed to the different chemical compositions of the materials, especially the filler content ratio. It is well known that the smoothest obtainable surfaces are achieved by curing the material in direct contact with a Mylar strip (23). The higher filler weight and volume of Universal Restorative 200 may have resulted in smoother surfaces in the Mylar strip group. It has been reported that surfaces formed with Mylar strips may have a resin-rich layer and poor physicomechanical properties. After polishing, the surface micromorphology of the composites is affected by the type, amount, size, and hardness of the filler particles. It is also affected by the flexibility of the polishing materials, the hardness of the abrasive, size, and the method of application (36). In our study, Ceram-X Duo yielded the highest mean Ra value (0.31 μm) after AAA, while the mean Ra value for this material was similar in the rubber and disc application groups. This situation may be caused by the ormocer structure as well as the glass particles in Ceram-X Duo (37). Universal Restorative 200 exhibited a less-rough surface than other materials (except for IPS Empress Direct). Although there is no difference between the materials in the rubber group, disc application may have contributed to the smoothness of the nanohybrid composites. Several studies have found that multi-step systems perform better than one-step systems (9,38). One-step systems can be implemented with a single polishing material, and smooth surfaces are provided in a shorter time (39). One study found that the texture of the final surface depends on the technique and material used (40), but there is no consensus on the materials and techniques that provide the smoothest surfaces for resin composites (41). According to our study, Optidisc (multi-step) created smoother surfaces and, therefore, lower staining susceptibility than Dimanto (one-step). The effectiveness of polishing discs containing aluminium oxide particles to create smooth surfaces tends to diminish gradually (39). The Dimanto polishing system contains particles impregnated with diamonds. Diamond is harder than aluminium. Therefore, diamond abrasive particles may cause deeper scratches on the surface of the composites, which may increase surface roughness. We found that a one-step polishing system did not produce the same surface quality on the resin composites. This is not attributable to the quality of the polishes but entirely to the interaction between the polisher and the composite resin.

In the present study, Mylar strip was associated with lower hardness values than the polishing systems. This finding is similar to other studies (8,42). Alfawaz, (43) investigated two polishing methods (a one-step [PoGo] and a multi-step [Sof-Lex] method) applied to two different composites (Z350 XT and Ceram-X). Mylar strips were chosen as the control group. The control group yielded lower hardness values than the polished groups, but there was no significant difference between the polishing systems. Tornavoi et al. (44) found that AAA did not affect the hardness values of resin composites, but there were significant differences in hardness between the materials. Schulze et al. (45) found that Knoop hardness values of resin composites increased significantly after AAA. In contrast, a previous study (46) reported that microhardness values of resin composites decreased significantly after AAA. In our study, hardness values of resin composites increased significantly after AAA. Factors such as the device used, light, humidity and heat (45) caused differences in the mechanical properties of the materials. Studies have shown that water absorption by the resin matrix and orifice temperature can change the cohesion between the matrix and inorganic particles, reducing the mechanical properties of these materials and causing them to degrade (44,47). The results obtained in our study showed statistically significant differences between dental composites and demonstrated that the type of composites used might also influence the hardness results obtained. In our study, the highest hardness values among all groups were observed in association with Universal Restorative 200, and the lowest hardness values were observed in association with G-Aenial Anterior. This may be attributable to the filler ratio of the composite, as well as the influence of the hardness of the inorganic filler on the general hardness of the material (8). In our study, zirconia particles may have affected the increase in the VHN values of Universal Restorative 200. Previous study (44) reported that, among different resin composites, the composite material (Z250-microhybrid) with silica and zirconia content was harder. The microhardness of resin composites depends on several factors, such as the content of the resin matrix and the type and shape of the particle. Moreover, the hardness of resin composite is directly related to filler particles (48). In this context, the difference in material contents in our study reflects differences in hardness values.

One of the limitations of this study was the evaluation of the color and surface properties of resin composites using an in vitro methodological approach. Within the methodological limitations, we aimed to mimic the effects on resin materials of aging processes that may occur in the oral environment in a short time to estimate the clinical performance of the resin composites. However, various factors in the oral environment, such as saliva, temperature, pH, and brushing, can affect the long-term color stability, surface roughness, and hardness of resin composites. Further studies using different polishing and ageing methods should be conducted on resin composites. It should also be noted that flat sample surfaces were used in the present study, and in clinical practice, restorations created with resin composites consist of convex or concave irregular structures.

5. CONCLUSION

Within the limitations of this in vitro study, it was concluded that:

Composite type, finishing/polishing, and AAA had statistically significant effect on surface roughness and hardness. The Mylar strip groups had smoother surfaces and less discoloration than the polishing groups. The Optidisc (multi-step) group exhibited more stain resistance and smoother surfaces than the Dimanto (one-step) group. Nanohybrid resin composite (IPS Empress Direct) and microhybrid resin composite (Universal Restorative 200) were associated with more favourable color changes and roughness values with Optidisc (multi-step) than with Dimanto (one-step). Polishing systems applied to composite materials increased the hardness values of the materials.

Conflict of interest: Authors declare no scientific and financial interest.

Funding: This study was supported by Scientific Research Projects Coordination Unit of Necmettin Erbakan University. Project number 201924001.

REFERENCES

[1] Roselino Lde M, Cruvinel DR, Chinelatti MA, Pires-de-Souza Fde C. Effect of brushing and accelerated ageing on color stability and surface roughness of composites. J Dent 2013;41 Suppl 5:e54–e61.

[2] Drubi-Filho B, Garcia LFR, Cruvinel DR, Sousa ABR, Pires-de-Souza Fde C. Color stability of modern composites subjected to different periods of accelerated artificial aging. Braz Dent J 2012;23:575–580.

[3] Taşın S, Celik G, İsmatullaev A, Usumez A. The effect of artificial accelerated aging on the color stability, microhardness, and surface roughness of different dental laminate veneer materials. J Esthet Restor Dent (Online publication) 2020. doi:10.1111/jerd.12567

[4] Gómez-Polo C, Portillo Muñoz M, Lorenzo Luengo MC, Vicente P, Galindo P, Martín Casado AM. Comparison of the CIELab and CIEDE2000 color difference formulas. J Prosthet Dent 2016;115:65–70.

[5] Tuncdemir AR, Aykent F. Effects of fibers on the color change and stability of resin composites after accelerated aging. Dent Mater J 2012;31:872–878.

[6] Tekçe N, Pala K, Tuncer S, Demirci M. The effect of surface sealant application and accelerated aging on posterior restorative surfaces: An SEM and AFM study. Dent Mater J 2017;36:182–189.

[7] Catelan A, Briso ALF, Sundfeld RH, Dos Santos PH. Effect of artificial aging on the roughness and microhardness of sealed composites. J Esthet Restor Dent 2010;22:324–330.

[8] Erdemir U, Sancakli HS, Yildiz E. The effect of one-step and multi-step polishing systems on the surface roughness and microhardness of novel resin composites. Eur J Dent 2012;6:198-205.

[9] St-Pierre L, Martel C, Crépeau H, Vargas MA. Influence of polishing systems on surface roughness of composite resins: polishability of composite resins. Oper Dent 2019;44:122-132.

[10] Shirinzad M, Rezaei-Soufi L, Mirtorabi MS, Vahdatinia F. Effect of accelerated artificial aging on translucency of methacrylate and silorane-based composite resins. J Dent 2016;3:92–100.

[11] Korkmaz Ceyhan Y, Ontiveros JC, Powers JM, Paravina, RD. Accelerated aging effects on color and translucency of flowable composites. J Esthet Restor Dent 2014;26:272–278.

[12] Paravina RD, Ontiveros JC, Powers JM. Accelerated aging effects on color and translucency of bleaching-shade composites. J Esthet Restor Dent 2004;16(2):117-127.

[13] Pires-de-Souza F, Casemiro LA, Garcia L, Cruvinel DR. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. J Prosthet Dent 2009;101:13–18.

[14] Sharma G, Wu W, Dalal EN. The CIEDE2000 color-Difference formula: Implementation notes, supplementary test data, and mathematical observations. Color Res Appl 2005;30:21–30.

[15] Paravina RD, Ghinea R, Herrera LJ, Bona AD, Igiel C, Linninger M, Sakaim M, Takahashi H, Tashkandi E, del Mar Perezet M. Color difference thresholds in dentistry. J Esthet Restor Dent 2015;27 Suppl 1:S1–S9.

[16] Lee YK. Comparison of CIELAB DeltaE(*) and CIEDE2000 color-differences after polymerization and thermocycling of resin composites. Dent Mater 2005;21:678–682.

[17] Sanko V, Sezer ÜA, Sezer S, Demirekin ZB, Eroğlu E, Türkaslan S. Investigation of the mechanical and color characteristics of microcrystalline cellulose containing dental composite resins. J Dent Fac Atatürk Uni 2020;30:181–187.

[18] Sagong H, Kim K, Kwon T. Effect of polymerization type and thickness on color stability of resin cements. Korean J Dent Mater 2013;40:297–302.

[19] Lee SM, Choi YS. Effect of ceramic material and resin cement systems on the color stability of laminate veneers after accelerated aging. J Prosthet Dent 2018;120:99–106.

[20] Sirin Karaarslan E, Bulbul M, Yildiz E, Secilmis A, Sari F, Usumez A. Effects of different polishing methods on color stability of resin composites after accelerated aging. Dent Mater J 2013;32:58-67.

[21] Dantas DCB, Mathias IF, Borges AB, Torres CG, Caneppele TMF. Effects of artificial accelerated aging on the optical properties of resin composites. Biosci J 2018;34:1105– 1113.

[22] Kunzelmann KH, Mehl A, Hickel R. Sliding wear of an experimental ormocer and 15 commercial composites, J Dent Res 1998;77:226 Abstr. no. 965.

[23] Sherif R, Abd El-Fattah W, Afifi R. Color stability and surface roughness of an organically modified ceramic (ormocer) and a methacrylate based composite resins (An in-vitro study). Alex Dent J 2020;45:100-105.

[24] Poggio C, Ceci M, Beltrami R, Mirando M, Wassim J, Colombo M. Color stability of esthetic restorative materials: a spectrophotometric analysis. Acta Biomater Odontol Scand 2016;2:95-101.

[25] Nasim I, Neelakantan P, Sujeer R, Subbarao CV. Color stability of microfilled, microhybrid and nanocomposite resins—An in vitro study. J Dent 2010;38 Suppl 2:137-142.

[26] Paravina RD, Roeder L, Lu H, Vogel K, Powers JM. Effect of finishing and polishing procedures on surface roughness, gloss and color of resin-based composites. Am J Dent 2004;17:262-266.

[27] Catelan A, Briso AL, Sundfeld RH, Goiato MC, dos Santos PH. Color stability of sealed composite resin restorative materials after ultraviolet artificial aging and immersion in staining solutions. J Prosthet Dent 2011;105:236–241.

[28] Pires-de-Souza F, Garcia L, Roselino L, Naves LZ. Color stability of silorane-based composites submitted to accelerated artificial ageing—an in situ study. J Dent 2011;39 Suppl 1: e18–e24.

[29] Koh R, Neiva G, Dennison J, Yaman P. Finishing systems on the final surface roughness of composites. J Contemp Dent Pract 2008;9:138–145.

[30] Lu H, Powers JM. Color stability of resin cements after accelerated aging. Am J Dent 2004;17:354–358.

[31] Kucukesmen HC, Kucukesmen C, Usumez A. Effect of aging procedure on surface roughness of different restorative material. J Health Sci (SDU) 2010;1:39-48.

[32] Pucinelli C, Silva R, Mellara T, Patricia G, Pires-de-Souza Fernanda, Lea S. Color stability and surface roughness of composites after artificial accelerated aging. J Dent Indones 2017;24:26–31.

[33] Zanin FR, Garcia Lda F, Casemiro LA, Pires-de-Souza Fde C. Effect ofartificial accelerated aging on color stability and

surface roughness of indirect composites. Eur J Prosthodont Restor Dent 2008;16:10-14.

[34] Rattacaso RM, da Fonseca Roberti Garcia L, Aguilar FG, Consani S, de Carvalho Panzeri Pires-de-Souza F. Bleaching agent action on color stability, surface roughness and microhardness of composites submitted to accelerated artificial aging. Eur J Dent 2011;5:143-149.

[35] Kaizer MR, de Oliveira-Ogliari A, Cenci MS, Opdam NJ, Moraes RR. Do nanofill or submicron composites show improved smoothness and gloss? A systematic review of in vitro studies. Dent Mater 2014;30:e41-e78.

[36] Aytac F, Karaarslan ES, Agaccioglu M, Tastan E, Buldur M, Kuyucu E. Effects of novel finishing and polishing systems on surface roughness and morphology of nanocomposites. J Esthet Restor Dent 2016;28:247-261.

[37] Magdy NM, Kola MZ, Alqahtani HH, Alqahtani MD, Alghmlas AS. evaluation of surface roughness of different direct resin-based composites. J Int Soc Prev Community Dent 2017;7:104-109.

[38] Rodrigues-Junior SA, Chemin P, Piaia PP, Ferracane JL. Surface roughness and gloss of actual composites as polished with different polishing systems. Oper Dent 2015;40:418-429.

[39] Antonson SA, Yazici AR, Kilinc E, Antonson DE, Hardigan PC. Comparison of different finishing/polishing systems on surface roughness and gloss of resin composites. J Dent 2011;39 Suppl 1: e9–e17.

[40] Schmitt VL, Puppin-Rontani RM, Naufel FS, Nahsan FP, Alexandre Coelho Sinhoreti M, Baseggio W. Effect of the polishing procedures on color stability and surface roughness of composite resins. ISRN Dent 2011;2011:617672.

[41] de Carvalho Justo Fernandes ACB, de Assunção IV, Borges BCD, da Costa GdFA. Impact of additional polishing on the roughness and surface morphology of dental composite resins. Rev Port de Estomatol Med Dent Cir Maxilofac 2016;57:74– 81.

[42] Korkmaz Y, Ozel E, Attar N, Aksoy G. The influence of one-step polishing systems on the surface roughness and microhardness of nanocomposites. Oper Dent 2008;33:44-50.

[43] Alfawaz Y. Impact of polishing systems on the surface roughness and microhardness of nanocomposites. J Contemp Dent Pract 2017;18:647-651.

[44] Tornavoi DC, Sato S, Silva LJ, Agnelli JAM, dos Reis AC. Analysis of surface hardness of artificially aged resin composites. Mat Res 2012;15:9–14.

[45] Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. Dent Mater 2003;19:612–619.

[46] de A Souza MB, Briso AL, de Oliveira-Reis B, Dos Santos PH, Fagundes TC. Influence of light-curing units on surface microhardness and color change of composite resins after challenge. J Contemp Dent Pract 2019;20:204-210.

[47] Chinelatti MA, Chimello DT, Ramos RP, Palma-Dibb RG. Evaluation of the surface hardness of composite resins before and after polishing at different times. J Appl Oral Sci 2006;14:188-192.

[48] Nithya K, Sridevi K, Keerthi V, Ravishankar P. Evaluation of surface roughness, hardness, and gloss of composites after three different finishing and polishing techniques: An in vitro study. Cureus 2020;12:e7037.

How to cite this article: Fidan M, Dereli Z. Effect of Polishing Systems on the Color and Surface Properties of Resin Composites in the Process of Accelerated Artificial Aging. Clin Exp Health Sci 2022; 12: 702-710. DOI: 10.33808/clinexphealthsci.1012098