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ORIGINAL RESEARCH

Evaluation of surface roughness and color changes of restorative materials used with different polishing procedures in pediatric dentistry

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Abstract

This study aimed to evaluate the color stability and surface roughness properties of four different restorative materials used in pediatric dentistry clinics as a result of four different polishing procedures. A total of 128 samples, 32 of each restorative material, were prepared by placing them in polyethylene molds with a diameter of 6 mm and a height of 2 mm, in accordance with the instructions of the manufacturers, to be polished with four different polishing procedures (n = 8). After finishing and polishing, the samples were kept in distilled water at 37 °C for 24 hours. Surface roughness and color stability measurements of the samples were then made. The Hysitron TI 950 TriboIndenter device in Mustafa Kemal University's Technology Research & Development Center was used for surface roughness test measurements, and the Ra parameter was taken as a basis. A spectrophotometer instrument (VITA Easyshade® Advance 4.0 (VITA Zahnfabrik, Bad Sackingen, Germany)) was used to determine color stability and color differences were recorded according to the CIEDE 2000 system. The lowest roughness values were observed in G-aenial restorative material polished with Super-Snap material, and the highest roughness values were observed in Equia material polished with Identoflex material. When all materials were evaluated, the smallest color change values were seen in G-aenial material polished with Super-Snap, and the most color change values were detected in Equia material polished with Identoflex. It was observed that the relationship between surface roughness and color change was statistically significant. The lowest color change and surface roughness values were observed in the G-aenial material polished with Super-Snap. For improved clinical results, the most appropriate polishing procedure should be chosen based on the restorative material used.

Keywords

Pediatric dentistry; Polishing procedures; Color change; Surface roughness

1. Background

Restorative materials commonly used in pediatric dentistry include resin-modified glass ionomer cements, conventional glass ionomer cements, compomers and resin composites [1]. Today, with the development of restorative materials, the filler contents have turned into nano particles instead of macro or micro particles, and the clinical use of composite resins containing nano fillers has become widespread [2]. The particle sizes and amounts of the restorative materials, the organic matrix and inorganic filler types, and the finishing and polishing materials applied determine the surface properties and polishability of the restorations [3]. It has been reported that non-porous restoration surfaces reduce bacterial dental plaque attachment, the risk of gingival tissue irritation, the risk of discoloration of the restorative material and the risk of long-term secondary caries [4]. A smooth restoration surface extends the life of resin materials and improves their appearance. Rough restoration surfaces can cause plaque accumulation, discoloration, gingival irritation and recurrent caries [5]. In addition, studies have determined that restorations with rough surfaces increase bacterial colonization [6]. Composite resin materials should have ideal surface hardness and low surface roughness after polishing. These properties should be preserved during long-term use in the oral environment [7]. The finishing and polishing techniques used vary with the type of restorative materials. The surface roughness of composite resins is pertinent to the composition of the material, its porosity, the composition of the polishing materials used, the size and the number of abrasive particles, and the polishing procedures. The amount of pressure applied during the polishing process, the difference in hardness between the abrasive material and the restorative material, the direction of the abrasive application surface, the time spent with each abrasive tool and the geometry of the abrasive tools also affect the surface porosity of the material [8]. A great variety of abrasives are available for finishing and polishing restorative materials. These include carbide compounds, aluminum oxide, silicon dioxide, diamond particles, zirconium silicate and zirconium oxide [9]. Studies have shown that the polishing system and the restorative substance have a direct impact on the results of finishing and polishing procedures [10]. Various studies have reported that many beverages consumed in daily life cause varying degrees of discoloration in restorations [11, 12]. In the studies conducted by Güler *et al.* [11], the effects of nine different beverages consumed in daily life (distilled water, coffee, sweetened coffee, tea, sweetened tea, red wine, artificial cream, cola and cherry juice) on the coloring of composite resins were evaluated and restorative materials were examined. The interaction of restorative materials and staining agents was found to be statistically significant ($p = 0.0001$). Well-polished restorative material surfaces increase aesthetic quality by minimizing surface porosity and discoloration [13]. The color alteration value limit that can be accepted in clinical practice, and that is most frequently used in literature reviews, is 3.3 [14]. It is important for dentists to know which polishing system provides sufficient surface quality in order to improve the aesthetics and longevity of restorative materials [2]. The aim of our study is therefore to examine the surface roughness and color changes on the restorative materials after different polishing applications used in pediatric dentistry and to determine the materials that show superiority in terms of surface roughness and color change. The determination of superior materials in terms of color stability and surface roughness will guide dentists and provide longer-lasting and more aesthetic restorations. The hypothesis of this research is that different polishing procedures will create different degrees of color change and surface roughness in the structure of restorative materials.

2. Materials and methods

2.1 Materials used

2.1.1 Restorative materials

Glass hybrid restorative material Equia Forte (2106121, GC, Tokyo, Japan), nano hybrid composite G-aenial Universal Injectable (220803A, GC, Tokyo, Japan), micro hybrid dual cure composite Fill-up (FE1094, Coltene Whaledent, Switzerland) and supra nano composite material Estelite Universal Flow Super Low (153EY2, Tokuyama Dental, Tokyo, Japan) used in the pedodontics clinic were also used in the current study. These restorative materials are listed in Table 1.

2.1.2 Polishing materials

In the current study, four different polishing systems, namely OptiDisc (Discs, Kerr, Hawe, SA, Switzerland), Sof-Lex (Discs, 3M ESPE, St. Paul, MN, ABD), Identoflex Composite Polisher (Rubbers, Kerr, Hawe, SA, Switzerland) and Super-Snap (Discs, Shofu, Tokyo, Japan) were used to perform the finishing and polishing processes which can be seen in Table 2.

2.2 Preparation of samples

A total of 128 samples, 32 from each restorative material were prepared for the current study. The samples were prepared in accordance with the manufacturers' recommendations, and were injected into polyethylene molds with a diameter of 6 mm and a height of 2 mm. Transparent tape (Dispodent, Istanbul, TR) and glass coverslips were pressed on the samples to remove excess material. The light-emitting diode (LED)beam filler device VALO (Valo, Ultradent, Utah, UT, USA), which produces light in the spectrum between 385 and 515 nm, was used to polymerize the samples with a light of 1200 mW/cm^2 for 20 seconds, in compliance with the manufacturer's instructions.

2.2.1 Creation of restorative material groups

In the current study, 32 samples were prepared from each restorative material. Restorative materials were randomly divided into four subgroups, with each group containing eight samples for different finishing and polishing processes. The samples to be divided into groups were initially numbered sequentially and randomly assigned to the groups, using the random (RAND) function command in the Excel program.

2.2.2 Finishing and polishing of samples

The samples obtained were randomly divided into various subgroups and then subjected to finishing and polishing processes. These processes were performed under water cooling, in compliance with the manufacturer's recommendations.

In the Sof-Lex system, the samples were kept in water cooling for 15–20 seconds, taking into account the grain order. Thick and medium-grained discs were applied at a speed of 30000 rpm, and fine- and super-fine- grained discs were applied at 10000 rpm in the same direction, provided that each disc was used once. Restoration surfaces were washed for 5 seconds after each disc was applied.

In the OptiDisc polishing system, the specimens were polished with thick, medium, thin and extra-thin discs, respectively, at a constant speed between 10000 and 20000 rpm. In each disc group, the surfaces of the restorations were polished for 15–20 seconds and washed for 5 seconds.

In the Identoflex Composite Polisher system, flame-shaped rubbers were used and polished in three stages as yellow (pre-polishers), gray (gloss) and white (high-gloss), polishers respectively. The samples were polished for 60 seconds to achieve high surface gloss, and then washed for 5 seconds.

In the Super Snap group, the samples were polished at 10000 to 20000 rpm for 15–20 seconds under water cooling with thick, medium, fine and super-fine discs, respectively. After each disc was applied, the sample surfaces were washed for 5 seconds and dried with air water spray.

2.3 Initial roughness and color value measurements of samples

After the samples were kept in distilled water for 24 hours, but before the color values were measured, the samples were dried with blotting paper. The initial color values of the samples in each group were measured with the help of a digital spectrophotometer (VITA Easyshade® Advance 4.0, VITA

TABLE 1. Restorative materials used and their contents.

Materiel	Manufacturer	Type	Contents	Particle Size	Filler Ratio
Equia Forte	GC, Tokyo Japan	Glass hybrid restorative material	Fluoro aluminosilicate glass		
G-aenial Universal Injectable	GC, Tokyo Japan	Nano hybrid composite	Methacrylate monomers, barium glass, silica	0.15 μm	69% by weight 50% by volume
Fill-up	Coltene Whaledent Switzerland	Micro hybrid dual cure composite	Trimethylolpropane triacrylate (TMPTMA), Urethane dimethacrylate (UDMA), Bisphenol A-glycidyl methacrylate (Bis-GMA), Triethylene glycol dimethacrylate (TEGDMA), Dental glass, methacrylate, zinc oxide amorphous silica	2 μm	65% by weight 49% by volume
Estelite Universal Flow	Tokuyama Dental, Tokyo Japan	Supranano composite	Bis-GMA, TEGDMA, Bisfenol A poliethoksimetakrilat (Bis-MPEPP), UDMA	0.2 μm	70% by weight 56% by volume

TABLE 2. Polishing systems used and their contents.

Materiel	Manufacturer	Abrasive/Type	Number of Stages
Sof-Lex	3M ESPE, USA	Discs coated with aluminum oxide (coarse, medium, fine, superfine) 60 μm, 29 μm, 14 μm, 5 μm	4 Stages
OptiDisc	Kerr, USA	Aluminum oxide coated discs (coarse, medium, fine, superfine) 80 μm, 40 μm, 20 μm, 10 μm	4 Stages
Identoflex Composite Polisher	Kerr, USA	Rubbers containing diamond particles	3 Stages
Super-Snap	Shofu, Japan	Discs coated with aluminum oxide and silicon carbide (coarse, medium, fine, superfine) 60 μm, 30 μm, 20 μm, 7 μm	4 Stages

TABLE 3.1. Color change and surface roughness values of restorative materials.

Categories	Ra			CIEDE2000		
	Avg ± Standard Deviation (SD)	Min-Max	p	Avg ± SD	Min-Max	p
G-aenial	95.5 ± 71.7 nm	95.5–71.7 nm	<0.001	1.7 ± 1.6	0.37–5.95	<0.001
Equia	394.3 ± 76.7 nm	394.3–76.7 nm		3.3 ± 2.6	0.54–11.98	
Fill-Up	206.6 ± 74.9 nm	206.6–74.9 nm		1.3 ± 0.3	0.59–1.95	
Estelite	155.8 ± 58.0 nm	155.8–58.0 nm		3.8 ± 1.2	1.17–5.80	

TABLE 3.2. Color change and surface roughness values of polishing systems.

Categories	Ra			CIEDE2000		
	Avg ± Standard Deviation (SD)	Min-Max	p	Avg ± SD	Min-Max	p
Super-Snap	184.04 ± 119.2 nm	21.150 ± 387.300 nm	0.02	2.61 ± 2.0	0.59 ± 6.6	0.069
OptiDisc	228.29 ± 128.2 nm	71.140 ± 483.700 nm		2.98 ± 2.0	0.37 ± 6.9	
Sof-Lex	172.57 ± 126.5 nm	32.770 ± 432.400 nm		1.86 ± 1.3	0.46 ± 5.8	
İdentoflex	267.24 ± 138.3 nm	114.350 ± 544.900 nm		2.62 ± 2.3	0.68 ± 12.0	

Zahnfabrik, Bad Sackingen, Germany).

After the finishing and polishing processes, the initial surface roughness values of the samples were evaluated with the Hysitron TI 950 TriboIndenter device by scanning areas of 40 × 40 μm. One scanned area was in the center point of each sample and four were in the peripheral points, for a total of five areas per sample. A Ra (nm) value was obtained by taking the arithmetic mean of the measurements of each restorative material.

2.4 Coloring the samples

After the initial surface roughness and color determination, the samples were incubated in cola solution in 2 mL tubes for 7 days at 37 °C in an oven (FN 500, Nüve, Hatay, Turkey) in order to enable the time-dependent color change analysis of the samples. The solutions were refreshed every 24 hours to maintain the carbonic gas level.

After the initial color values were measured, the final color measurements of the samples kept in the cola solution were measured with the help of the same spectrophotometer device. The color difference between the final color measurements and the initial color measurements was calculated with the CIEDE 2000 formula and recorded as the ΔE_{00}* value.

3. Statistical analysis

The Statistical Package for the Social Sciences (SPSS)21 (IBM Corp., Armonk, NY, USA) program was used to analyze the data in the current study. In the statement of descriptive measures, mean, standard deviation and minimum-maximum statistics are given. Comparisons by materials and polishes were made using Analysis of Variance (ANOVA) and Kruskal-Wallis tests. The Least Significant Difference (LSD) test was used for pairwise comparison after the parametric test, and Mann Whitney U tests with Bonferroni correction ($p = 0.05/6 = 0.008$) were used after the nonparametric test. Pearson and Spearman correlation coefficients were used in the analysis of the relationship between continuous variables. The cut-off value for all tests was set at 0.05.

4. Results

Color change and surface roughness values of restorative materials are indicated in Table 3.1, while surface roughness and color change values of polish materials are indicated in Table 3.2.

When the surface roughness values determined as a result of the Shock Pulse Monitoring (SPM) measurement of the restorative materials were examined according to the brands, the average roughness values (Ra), from lowest to highest, were:

G-aenial (95.5 nm) < Estelite (155.8 nm) < Fill-up (206.6 nm) < Equia (394.3 nm).

The surface roughness values of the restorative materials were examined after different finishing and polishing processes, and the findings are shown in Table 4.

When the surface roughness values of the polishing materials were examined according to the brands, the values found were as follows:

Sof-Lex (172.57 nm) < Super-Snap (184.04 nm) < OptiDisc (228.29 nm) < Identoflex (267.24 nm) from the smallest to the largest.

When all materials were examined, the smallest surface roughness values were detected in the G-aenial group polished with Super-Snap material (31.17 ± 10 nm), and the largest roughness surface values were detected in the Equia group polished with Identoflex material (453.43 ± 103.5 nm.)

When the color change values of the restorative materials were examined according to the brands, the average color change values (ΔE_{00}), from the lowest to the highest were:

Fill-up (1.3) < G-aenial (1.7) < Equia (3.3) < Estelite (3.8).

The change of color values of the restorative materials were examined after different finishing and polishing processes, and the data obtained are shown in Table 5.

When the color change values that occurred after the application of polishing materials were examined according to the brands, the average color change values (ΔE_{00}), from the lowest to the highest, were:

Sof-Lex (1.86) < Super-Snap (2.61) < Identoflex (2.62) < OptiDisc (2.98).

When all materials were examined, the lowest color change values were found in the G-aenial group polished with Super-Snap material (0.91 ± 0.21), and the highest color values were found in the Equia group polished with Identoflex material (4.7 ± 3.9).

According to the results of Spearman correlation analysis, there was a statistically significant relationship between color change and surface roughness ($r = 0.255$; $p = 0.004$). Materials with higher surface roughness showed more coloration.

5. Discussion

The longevity and aesthetic success of restorative materials is directly related to the materials' surface smoothness and color stability [15]. It is very important to obtain bright and smooth restoration surfaces for restorations that are aesthetic, long-lasting and easily tolerated by the patient [16].

The effect of finishing and polishing procedures on the surface roughness and color stability of restorations is well known [17]. It has been shown that the use of polishing rubbers alone is not sufficient to obtain an ideal or acceptable restoration surface [18]. It is known that multi-stage finishing and polishing procedures produce more successful restoration surfaces in the long run [19]. Atomic force microscopy (AFM), Scanning probe microscopy (SPM), Scanning electron microscope (SEM) and profilometers are frequently used to evaluate the surface properties of restorative materials [20].

AFM, unlike profilometry, is a high-resolution, alternative, up-to-date method at the nanometer scale. As AFM has some important advantages, such as visualizing the three-dimensional (3D) image of the surface, it holds great promise for the examination of biomaterials [21]. In dentistry, visual or instrumental methods are used to measure color changes in restorative materials. Because the visual color selection method is subjective and can be affected by many different factors, colorimeters, spectrophotometers, spectroradiometers, digital cameras and imaging systems have begun to be used

TABLE 4. Surface roughness values of restorative materials polished with different polishing systems.

Ra	Super-Snap	OptiDisc	SofLex	İdentoflex	
	Avg ± Standard Deviation (SD)	Avg ± SD	Avg ± SD	Avg ± SD	*p*
G-aenial	31.17 ± 10 nm	186.21 ± 68.28 nm	44.21 ± 11.00 nm	120.4 ± 7.02 nm	<0.001
Equia	342.85 ± 40 nm	426.87 ± 36.12 nm	354.00 ± 48.73 nm	453.43 ± 103.50 nm	0.002
Fill-Up	195.36 ± 47 nm	145.47 ± 37.90 nm	185.71 ± 71.13 nm	299.86 ± 36.16 nm	<0.001
Estelite	166.78 ± 54 nm	154.60 ± 65.00 nm	106.39 ± 41.10 nm	195.31 ± 36.37 nm	0.013

TABLE 5. Color change values of restorative materials polished with different polishing systems.

CIEDE	Super-Snap	OptiDisc	SofLex	İdentoflex	
	Avg ± Standard Deviation (SD)	Avg ± SD	Avg ± SD	Avg ± SD	*p*
G-aenial	0.91 ± 0.21	3.17 ± 2.30	1.33 ± 1.0	1.56 ± 1.13	0.080
Equia	3.78 ± 2.00	3.29 ± 2.09	1.63 ± 0.8	4.70 ± 3.90	0.119
Fill-Up	1.09 ± 0.41	1.34 ± 0.17	1.05 ± 0.18	1.52 ± 0.24	0.004
Estelite	4.64 ± 0.86	4.14 ± 0.36	3.44 ± 1.42	2.82 ± 1.12	0.014

in color measurements. Spectrophotometers are the most frequently used devices in dentistry for the evaluation of color changes in dentistry that cannot be perceived by the human eye, and the instruments can evaluate colors at different wavelengths [22]. In the research conducted by Pusateri *et al.* [23], it was suggested that the VITA EasyShade® spectrophotometer was the most reliable device among color measurement devices such as VITA EasyShade®, ShadeVision®, SpectroShade® and ShadeScan®, with a rate of 96% in the evaluation of the colors of restorative materials. The results of the measurements obtained with a spectrophotometer are converted into three different color parameters based on the Commission Internationale de l'Elcairage (CIE)L*a*b* and CIEDE 2000 color systems and calculated as ΔE* values in line with these values [24]. It has been reported that the CIEDE 2000 formula reflects the color differences that the human eye can detect better than the CIE Lab formula [25].

It has been proven that the critical surface roughness value (Ra) required for bacteria to adhere to the restoration surface is 0.2 μm [26]. Mei *et al.* [27], in an *in vitro* study, reported that the adhesion of streptococci increased as the surface roughness increased on composite surfaces with different roughness values. Chung reported that a surface roughness value of less than 1 μm indicated an optically smooth restoration surface. In the studies conducted by Weitman and Eames and Shintani *et al.* [28, 29], it was reported that there was no difference in plaque accumulation on surfaces with Ra values in the range of 0.7–1.4 μm. In the current study, the most successful results among the four different restorative materials that were polished different finishing and polishing processes were found with Super-Snap in the G-aenial group (0.03 μm). These results show that the most suitable restorative material polishing procedure combination should be selected in order to obtain the most successful results, which are below the required critical surface roughness value.

Yamanel *et al.* [25], in their study, suggested that due to the very small size of the inorganic filler particles in the structure of the restorative materials containing nanofillers, smoother surfaces could be obtained after the finishing and polishing of these materials than after that of microhybrid composites. In the current study, the nanohybrid restorative material G-aenial was found to show statistically significantly less surface roughness than the microhybrid restorative Fill-up.

Mallya *et al.* [30] examined the surface roughness of three different glass ionomer-containing materials with three different finishing and polishing procedures. They found that the surface roughness values of single resin-free glass ionomer cement were higher than those of other glass-ionomer materials containing resin, and that the presence of resin in the structure of the materials reduced the surface roughness and produced smoother surfaces [30].

Similarly, in the current study, the surface roughness of the resin-free Equia material was found to be significantly higher than that of other resin-containing restorative materials.

In another study evaluating the surface roughness of restorative materials containing different glass ionomers, it was reported that resin-modified glass ionomer cement, giomer and compomer showed lower roughness values. The researchers stated that the glass particles in these materials dissolve less because they are embedded in a polymer resin, which is why restorative materials with higher resin content show lower roughness values compared to other restorative materials [31].

In their research, in which they investigated the effect of finishing and polishing systems on the surface roughness of three different hybrid and nanofilled composites, Bayraktar *et al.* [32] reported that nanofilled composite samples produced lower surface roughness than hybrid composite samples after finishing and polishing processes. This was contrary to our hypothesis. This difference may be attributed to the different content and particle sizes of the restorative materials used.

Ilday *et al.* [33] reported that brighter and smoother surfaces were obtained after polishing with aluminum oxide-containing discs (Sof-Lex, 3M ESPE) than after polishing with tires containing fine diamond particles (Astropol, Ivoclar, Vivadent) and diamond finishing burs.

In the current study, Identoflex polishing rubber containing diamond particles produced the highest roughness value. This may be due to diamond particles forming more rough surfaces on restoration surfaces after finishing and polishing processes, as they are harder than silicon carbide and aluminum oxide particles.

It has been reported that discs containing aluminum oxide create smoother surfaces as they abrade the resin matrix and filler particles evenly [34]. While multi-stage polishing systems contain smaller particles in each step to remove the scratches created by the previous step, this is not the case in single-stage systems. In single-stage systems, the grain size becomes more important in order not to create scratches on the surface.

The results of the current research indicated that the same polishing procedure did not create the same level of surface quality in all restorative materials. In line with these findings, it is thought that not only the polishing procedure, but also the interaction of the polishing procedure and the restorative material, determines the surface quality.

Tooth-colored restorative materials may undergo color change as a result of various internal or external factors. While the internal coloration is the coloration that occurs due to the material's own structure, the external coloration is a coloration that occurs as a result of contact with various coloring agents [35]. In scientific studies, the visual perceptibility of the color change or its clinical unacceptableness is expressed by the fact that the ΔE_{00} value is above the determined threshold value. This threshold value has been determined with different numbers by various researchers, but a consensus has not been reached [36]. For example, Yu *et al*. [37] accepted the value 2.6, Karaman *et al*. [14] accepted the value 3.3 and Paravina *et al*. [38] accepted the value 3.7 [35]. The color change value limit that can be accepted in clinical practice, and that is most commonly used in the literature review, is 3.3 [14]. In the current study, the color change value limit was accepted as 3.3 in accordance with the literature.

In the study by Ardu *et al*. [39], in which they compared the coloration of 11 hybrids and 1 microfilled composites according to the CIE Lab system, they obtained the lowest color change values in the microhybrid composite group, similar to the current work.

Nasim *et al*. [40], in their study evaluating the color stability of microhybrid, nanohybrid and microfilled composite resins, reported that the color stability of micohybrid composite resins was higher than that of nanohybrid and microfilled composites.

They thought that the greater color change of the nanohybrid composite than the microhybrid composite might be due to the resin matrix nature and potential porosity in the aggregated filler particles as well as to the porosity of the barium glass fillers.

Iazetti *et al*. [41] reported in their research that the color stability of restorative materials containing fluoride may be lower because fluoride is a water-soluble component. Similarly, in the current work, Equia material containing fluoride showed more color change than other materials.

In another study by Gönülol and Yılmaz, it was concluded that restorative materials with smaller particles do not always show less coloration, and it was stated that the coloring of restorative materials is also related to the monomer structure, filler particle ratios and surface irregularities [12]. In the current study, restorative materials with smaller particles did not show less coloration, suggesting that properties of the restorative materials other than the particle structure also had important effects on the coloration.

The resistance of restorative materials to discoloration is affected by parameters such as the resin matrix structure, water absorption of the restoration, the filler particles' structure and size, and the continuity of the resin matrix-filler particle connection, as well as the finishing and polishing processes applied to the restoration surface. For this reason, the clinical success of different restorative materials to which the same polishing procedure is applied may differ [38].

In another study by Aydın *et al*. [42], in which different finishing and polishing systems were used to evaluate the composite resins' color change and surface roughness, they found the lowest color change values in the Clearfil Twist Dia group, which is a polishing rubber with diamond spiral content. The difference in their results and those of the current study may be due to the difference in the color system and colorant solution used.

In the research by Korkut *et al*. [36], in which they analyzed the effects of seven different polishing systems on the coloring of microhybrid and nanohybrid composite resins colored with coffee, they obtained the highest change of color values in the Super-Snap group, unlike in the current study [11]. This was followed by OptiDisc and Sof-Lex materials, respectively. The different results in the literature can be attributed to variables such as polishing time, the speed of the handpiece used, water cooling, applied pressure, dexterity and operator experience. This difference may also be due to the fact that the OptiDisc and Sof-Lex polishing materials used in Korkut *et al*.'s [34] study were applied without water cooling.

In the research by Schmitt *et al*. [43], the researchers examined the color change and surface roughness of samples containing nanofillers and microhybrid composite resins after they were subjected to Sof-Lex and Pogo finishing and polishing systems. They reported that the Sof-Lex polish system produced higher color stability and lower surface porosity, similar to the current study [43].

The abrasive particles only need to be harder than the filler particles to be able to abrade the resin matrix and prevent the filler particles from protruding. On the other hand, in order to prevent scratches on the composite surface, the abrasive particles must be small in structure. Due to their smaller particle size of the discs coated with aluminum oxide, the Sof-Lex polishing system creates lower surface roughness values and high color stability.

Various studies with a positive correlation between color change and surface roughness have been identified in the literature evaluating the color change and surface roughness of restorative materials. In the current study, it was determined that there was a statistically significant relationship between surface roughness and color change, and that materials with higher surface roughness showed more coloration. The relationship between surface roughness and color changes for each restorative material and polishing systems was separately evaluated according to Pearson and Spearman correlation analyses. When the correlation between color change and surface roughness in G-aenial material and Super-Snap material was examined according to these analyses, it was observed that there was a significant relationship between surface roughness and color change. It is recommended the number of samples in future studies be increased to produce more meaningful results.

6. Conclusions

As a result of the findings obtained, it was determined that the finishing and polishing systems had significant effects on the surface roughness. It has been seen that the effectiveness of finishing and polishing techniques in terms of color change and surface roughness depends on the restorative material to which they are applied. It is recommended that more clinical studies be conducted to acquire more accurate findings due to different factors such as saliva, blood, isolation and difficulty in working in the oral environment.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

OP and BB—designed the research study; OP—performed the research; OP and BB—analyzed the data; OP—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Hatay Mustafa Kemal University Non-interventional Clinical Research Ethics Committee (04/10/2021-02) and complied with the principles of the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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